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A STUDY OF PNEUMATIC SOLID WASTE COLLECTION SYSTEMS AS EMPLOYED IN HOSPITALS

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This report summarizes a study that assesses the technical and economic feasibility of pneumatically transporting hospital solid waste. Three hospitals employing pneumatic collection systems were surveyed. Variations in systems design and utilization were investigated and reported upon. Cost information was accumulated and analyzed for each hospital. Operational, performance and environmental analyses were performed for all systems involved. This report should be helpful to hospitals already employing pneumatic systems from the standpoint of optimizing operating procedures and should be further helpful for new installations from a design standpoint.

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1974

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FOREWORD

The problem of solid waste management in hospitals has been and continues to be of major concern to hospital administrators. The nature of the waste requires that special consideration be given to handling, processing, and disposal. The past increase in the use of disposables in place of reusables has increased per patient solid waste generation levels to new highs. The cost of hospital solid waste management adds to other already high hospital systems costs. In light of these problems, careful consideration is being given to devising systems which are effective from both a cost and an environmental point of view.

This report examines pneumatic transport of solid wastes, a method which appears to offer both environmental and economic benefit when properly utilized. It is the purpose of this report to discuss the state of the art of pneumatic transport of hospital solid waste and to make broad recommendations to improve systems use and design.

Although, there have been some editorial revisions, this publication is essentially as delivered from the contractor.

Harvey W. Rogers, of the Systems Management Division of OSWMP, served as project officer for this contract effort.

--ARSEN J. DARNAY
Deputy Assistant Administrator
Solid Waste Management

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SUMMARY OF FINDINGS

1. In an effort to reduce operating costs and improve efficiency in the internal transportation of solid waste, over 160 American hospitals have installed, or contracted for, pneumatic tube transport systems. Approximately 300 additional hospitals are currently investigating the possible advantages of installing such a system.

2. In the majority of such installations, the basic designing of the systems has been performed by system vendors, as to type of system to be used, number of stations, length of run, speed of operation, full-vacuum or gravity-to-vacuum, single or multiple bag loading, mechanical and electrical elements, safety devices, structural strengths, and location of components; rather than by independent, professional consultants with in-depth experience in such systems.

3. In very few cases have detailed feasibility studies been performed on a professional level before the decision has been made to install such systems. As a result, the true economic savings, or the additional operating costs, have been unknown by the hospital administration until as long as two years after the systems have been in operation.

4. The capital costs of such installed systems have increased considerably over the past 10 years with some of the current installations amounting to over $750,000.

5. The installed systems are not being used to the full extent practicable by many hospitals and much of the solid waste is being hand carted around the pneumatic transport system. With under-utilization, the potential operational savings are seriously reduced.

6. Due to this under-utilization of the systems in the hospitals surveyed in this study, none were saving enough labor expense to recapture the capital investment in the system. However, if utilization is increased to the levels reocmmended in this report, the investment could be recaptured on a long-term basis by labor savings in each of the three hospitals, when compared

to costs of hand hauling all wastes by the more conventional cart method.

7. The reasons for under-utilization are many and varied:
   a. System mechanical failures and high maintenance factors.
   b. Limitations in the size of tube diameter and system power, and the consequent size of load the system will handle.
   c. Management decisions in individual hospitals that certain items will not be transported through the system (such as metal cans, glass bottles, and potentially infectious materials) for fear of breakage, noise, contamination, or damage to the system.
   d. Feelings on the part of management that hand carting of waste materials can be done more efficiently, due to the generating points of the materials versus the configuration and loading stations of the pneumatic system.
   e. The preference of management for hand cart waste collection methods in many areas as a more efficient method for clearing the floors.
   f. The hours of operation permitted the pneumatic system.

8. Maintenance costs for such systems have proven to be high, due to a combination of design and construction weaknesses and overloading or improper loading of the system by operating personnel.

9. The efficiency and speed of operation of the pneumatic transport system varies extensively between the designs of the various vendors. The gravity-to-vacuum, heavy-wall, multiple bag systems, while more expensive to purchase and install, are superior from a design and construction viewpoint; operate more efficiently; handle far larger loads per hour; and have the lowest operating costs. The weakest and most inefficient systems are the thin wall, single bag, full-vacuum systems; particularly where a single tube and suction fan handles both solid waste and soiled laundry.

10. Virtually all such transport systems are designed to accept waste in a bagged condition. Bag breakage or ripping presents a serious problem during transport, due in many instances to poor system design or construction. With all but the heavy-wall, gravity-to-vacuum systems, loose waste presents operational problems. Bagging of all waste has proven expensive. As

petroleum-based plastic bags are normally used, the increasing scarcity of these materials may present operational problems in the future.

11. From the environmental aspects, all such pneumatic systems are an improvement over the straight gravity chutes, or hand hauling methods, for transporting solid waste. When the collector boxes at the end of the transport tube line are close-connected to attrition mills or compactors, the environmental benefits are further increased.

12. The major environmental weaknesses in the pneumatic tube systems, assuming they are operating properly, involve the collector boxes at the end of the tube, the fan rooms, and the filtration of the effluent air from the fans. With bagged waste and the speed of bag travel, the vacuum tubes appear to be relatively self-cleaning.

13. The sound levels of the systems while in operation are relatively low and do not appear to be annoying to patients. Odor levels are not objectionable. The limited bacteriological testing that has been performed did not reveal pathogens of any significant level. The systems appear safe to use from an operator viewpoint. Fire safety codes are satisfied.

14. User acceptance varied considerably between hospitals in view of operational and maintenance problems experienced. Amounts of waste transported by the pneumatic system ranged from a low of 25.1% to 38.8% to 60.3% among the three hospitals, with the balance of the waste hand cart transported.

15. It is possible to both modify and expand all three of the systems studied, particularly in the collection system at the end of the line, or if additional wings are constructed.

INTRODUCTION

In June 1973, Ross Hofmann, Associates was employed by the Environmental Protection Agency to study solid waste management practices in hospitals. Particular emphasis was to be placed on pneumatic transport systems for the moving of solid waste through a hospital complex. Three hospitals were selected for in-depth study of their pneumatic transport systems: St. Mary's Hospital in Duluth, Minnesota; Martin Luther King, Jr. Hospital in Los Angeles, California; and the Veterans Administration Hospital in San Diego, California.

The following report was a result of the Consultant's work. It has been divided into two main sections. The first section covers the principal factors involving solid waste management in hospitals. It describes the magnitude of hospital solid waste and the environmental effects from it; the various management methods that are used; and the problems that are encountered as a result of both internal and external constraints. It describes in detail the equipment that is used in hospitals for pneumatic transport systems and for systems of final reduction and off-site removal of solid waste. This material is covered in Chapters 1 through 4 and sets the background for any study of solid waste management and transport within a general hospital.

The second section, covered by Chapters 5 through 12, concentrates primarily on the three hospitals that were surveyed and the problems they have encountered with the use of pneumatic solid waste transport systems. It analyzes the hospitals, their architecture, the systems they employ, the loads of waste they must handle; and it analyzes the performance of their systems, ranging from costs to environmental affects. The conclusion of this section rates and compares the systems the three survey hospitals are using.

The delivery of health care has now become the largest retail industry in America. Hospital operating costs account for approximately one-third of this enormous expenditure. Labor payrolls account for almost 65 percent of total hospital expenses, and hospitals are turning increasingly to methods for labor reduction, including automation and mechanization. In the management and transport of hospital solid waste, mechanization is a fairly recent development, with pneumatic tube systems the method that has attracted the most interest.

The principle of a pneumatic tube system for the transmission of solid objects is over 50 years old. The use of large diameter tubes (over 14 in. outside diameter) for this purpose dates back to 1941, and the designs involve either fully pneumatic or gravity transfer in vertical chutes, combined with fully pneumatic transfer in horizontal and rising runs. In all cases, a suction principle rather than a pushing (or blowing) principle has been used.

The first such systems that were installed in hospitals in the United States were an outgrowth of systems originally developed for moving linens in commercial laundries. Only linens, not solid waste, were moved pneumatically initially in hospitals. The first such system for handling solid waste in a U.S. hospital was not installed until the midsixties. While many advances for pneumatic tube transfer have been designed in Europe, only one such system, designed originally in Sweden for use in solid waste collection, has been introduced in U.S. hospitals to date.

As is usually the case with system designs that have been developed for one field and adapted to another field, the conversion of large diameter pneumatic tube systems from laundry and industrial use into a structure and operational organization as complex as a modern U.S. hospital has presented innumerable problems: to the engineers and architects, the manufacturers, and the hospital personnel. The economic feasibility of many systems that have been installed or contracted for has not yet been proven. Users of certain installations have registered serious complaints with the authors of this Report as to the technical merits of such systems.

The quantity of such systems installed to date in hospitals is still limited, but is growing. Sixty-one are claimed by ECI Air-Flyte Corporation, with an additional 68 on order; 23 in total installed and on order by Trans-Vac Systems; eight by Envirogenics Company; two by American Sterilizer Company; and six by other firms. It is felt that an in-depth study, under the sponsorship of the United States Government, will greatly contribute to further knowledge of these systems in view of the limited research published to date.

In the Report that follows, we have analyzed hospital solid waste management and pneumatic transport systems from several viewpoints and with separate disciplines. At first glance, these separate evaluations may appear to overlap, or even duplicate each other. We believe that this is not the case, and that each evaluation interfaces with the next one in a logical progression, and that the data assembled by one discipline or phase is essential to the next.

Each of the three pneumatic solid waste transport systems studied handles both solid waste and soiled laundry. Therefore, there is of necessity an interaction between these two types of materials in the complete system, when a common tube is utilized for both materials, and a possible interaction when separate tubes and a common suction fan are used. Although many of the details of laundry removal were not studied, since this effort was intended to address only solid waste management practices in hospitals, the interaction and impact of the linen removal system on the solid waste removal system was analyzed, evaluated, and the results included in this Report.

With continually rising operational costs in hospitals, coupled with the increasingly serious environmental problems in solid waste management, considerable interest in the results of the study have been expressed to the research team by hospital personnel in various parts of the country, by governmental agencies, and by the vendors of solid waste management equipment. It is hoped that the data given in the Report will prove useful in assisting hospitals in solving these problems, as well as indicating some of the areas in which further in-depth research may produce beneficial results and guide lines.

To obtain the background data covered in the first four chapters of this report, over 100 medium to large size hospitals have been researched by the survey team, in addition to the three institutions that are described in depth. We would like to express our appreciation to the administration and staffs of all the hospitals who cooperated so completely in the investigations of their solid waste management systems, and to the Project Director and Staff Engineers of the Office of Solid Waste Management Programs, U.S. Environmental Protection Agency, whose constructive criticism and guidance was invaluable in the preparation of this Report.

1-SOLID WASTE MANAGEMENT IN HOSPITALS

Over the past 20 years, various surveys have been conducted and articles have been published on the amount and types of solid waste being generated by hospitals. Unfortunately, a review of this material, which is quite limited, indicates a certain amount of disagreement among the researchers as to the magnitude of the problem. There is not a firm consensus of opinion as to the amount of solid waste generated by hospitals, which departments generate how much, and the make-up of the waste. Most surveys have measured the solid waste in terms of weight, in pounds. The measurements have been limited usually to the total weights generated by a relatively few hospitals. The usual procedure has been, then, to divide the patient census of the hospital into the total weight of waste recorded and to arrive at a figure of "X" pounds "per patient day" as the critical factor in solid waste analysis. The cube or volume of the waste, which is equally important in designing solid waste management systems, does not seem to have been recorded in most surveys.

It is for this reason, probably, that figures have varied considerably between hospitals. Solid waste is generated by *people*, by the *activities* in which people are engaged, and is affected by the size and complexity of the building in which the activities take place. "People," in a hospital setting, includes much more than patients. It must include all the staff and all the visitors. Hospitals do not staff on an identical basis. The ratio of staff to patients varies as much as 50 percent between hospitals, depending on the work patterns and the level of efficiency.

Hospitals do not perform identical work loads per patient. One may have the bulk of its cases as minimal care. Another may be engaged in very sophisticated and intensive care. Another may have heavy teaching and/or research activities and large research laboratories and animal quarters. Another may have thousands of outpatient and emergency visits annually. One may be crowded with visitors, another extremely light in this respect.

Hospitals with identical patient census figures vary somewhat in size and architectural layout. Theoretically, this should not affect the solid waste load generated if waste comes strictly from "people activities." For some reason (that may be from attitudes on the part of staff and visitors), architectural design affects the waste generated to some degree.

THE SIZE OF THE HOSPITAL COMMUNITY

In attempting to assess the impact on the United States of the solid waste load generated by all hospitals, a review of the industry as a whole, and its work load, reveals some interesting facts. Hospitals represent a major sector of the so-called "health care" industry. By 1973, it is estimated that American health care expenditures had risen to $94.1 billion, surpassing education as the largest service industry. Hospital care costs have reached $36.2 billion.[1] Sales by manufacturers to the health care industry are estimated to be $3 billion.[2]

However, the sheer quantity of acute medical care, rated by average number of inpatients staying in hospitals, has not changed substantially in the past 20 years, as can be seen from a review of the statistics published by the American Hospital Association. The number of hospitals has increased 7 percent. A.H.A. registered hospitals in 1955 numbered 6,596; a high point of 7,172 was reached in 1967; and by 1972 this had declined to 7,061.[3]

The number of available beds actually has declined. With 1,604,000 in 1955, by 1965 this had increased to 1,704,000, and dropped to 1,550,000 by 1972.[4]

Average daily patient census has fallen as well. In 1955 it was calculated to be 1,363,000, rising to 1,430,000 in 1963, and falling by 1972 to 1,209,000, the lowest since the late 1940's. Hospital personnel looking after these fewer patients has more than doubled over this period, rising from 1,301,000 in 1955 to 2,671,000 by 1972.[5]

A similar rise has been seen in the number of admissions, a statistic that has had a direct connection to cleaning rooms of waste to prepare for new patients, and to the number of patients and visitors going through the system. In 1955, 21,073,000 patients were admitted to hospitals. The figure shows a regular increase each year, with 33,265,000 patients admitted annually for 1972. A similar increase in activity is seen in annual number of outpatient visits, which have increased from 99,382,000 in 1962 to 219,182,000 by 1972.[6]

It has been estimated that since 1954 the total solid waste load of all hospitals combined has increased 350 percent in the United States.[7] Admissions have increased only 57 percent; outpatient visits by 120 percent; and staff by 105 percent. Other factors obviously have increased the solid waste output.

Most administrators feel that the bulk of the increase has come from the quantity and type of care rendered. When inflation is removed as a contributing factor, this would appear to be the case. Care and treatment of hospital patients has become more complex; the number of procedures, injections, I. V.'s, treatments, and medications given the average patient has risen geometrically in 20 years. Each procedure leaves a residue of solid waste to be disposed of.

THE IMPACT OF DISPOSABLES

Probably the greatest effect on the solid waste load generated by hospitals comes from the use of paper, foil, glass, and plastic "disposable" products, as against reprocessing items for further use. Disposables range in medical items from syringes and hypodermic needles, to surgical dressings and complete operating room patient drapes, to entire bedside sets of basins, cups, and pans. They include the containers for entire meals when the dietary department has switched to "convenience" foods. And they include tremendous quantities of paper containers from vending machines that hospitals have installed in snack bars. They include the millions of plastic bags used in a year to line waste baskets and trash cans and to transport waste. All of these items are designed to be used once and thrown away.

Not only do the products add enormously to the warehousing and solid waste problems; all of them are packaged in further quantities of plastic and paper, and the packaging has become much more elaborate as each year passes, in order to increase the eye appeal and saleability of the product. It is currently estimated that the packaging of the disposable products adds a solid waste load that exceeds that of the products themselves.

The phenomenon of packaged disposables is an outgrowth of consumer merchandising of the thousands of items we buy in drug stores, super markets, and variety stores. The theory was originally sold to hospitals by a few large hospital supply dealers on the basis that they would save the hospital processing labor and therefore operating cost. The hospitals, always pressed for capital funds to purchase processing equipment, and able to obtain operating dollars by raising rates to patients and third party reimbursers, welcomed the disposables with open arms. Unfortunately, it now has been discovered that, after approximately 18 years of intensive merchandising of these products, many hospitals actually have experienced a net increase in personnel due to the number of staff needed to store, issue, and inventory the disposables.

The trend toward disposable versions of hospital products started with those items that were the most difficult to clean, package, sterilize, and maintain in a reusable version; while at the same time offering possibilities of an extremely low cost throw-away substitute. The first items were hypodermic needles, syringes, and tubing of various types. These products were followed quickly by "sharps" (cutting blades), laboratory petri dishes and slides, patient bedside utensils, food service settings, I.V. and topical solution administration sets, surgical and examining gloves, surgical trays and sets for O.R. and the floors, surgical drapes and clothing, and even bed sheets.

From 1973 figures that are based on reports to the Department of Commerce and published by trade magazines for the surgical and hospital supply industry, the enormous production of disposable medical and surgical supplies in the United States can be seen. The dollar totals are based on manufacturers' selling prices. The cost to the consumer would be approximately double these figures (Table 1).

In addition to the items made from plastics, textiles, glass, and metal by the hospital supply manufacturers, there are the millions of bottles of irrigating and intravenous solutions in glass or plastic, as well as the packaged "unit dose" medications, supplied by the pharmaceutical manufacturers, in plastic, paper, and foil, which are purchased weekly by the hospitals.

The average disposable product is relatively low priced. To give an idea of the enormous volume of solid waste they have created, we find that the annual sale of disposable products to hospitals has increased by approximately $700 million in 18 years.[8] If we convert this huge annual dollar purchase into pounds and cubic volume, we find that by 1973, disposables had more than doubled the solid waste load in American hospitals.

TABLE 1

MEDICAL AND SURGICAL SUPPLIES

Disposable Product	1973 Sales Volume at Manufacturing Level
Hypodermic needles, disposable	$ 80,400,000
Hypodermic needles, "reusable"	7,100,000
Syringes, plastic	37,500,000
Syringes, other	51,300,000
Dressings, bandages	76,600,000
Adhesive plaster and self-adhering bandages	158,300,000
Surgical and medical gauze	8,900,000
Cotton balls and cotton wool	30,500,000
Sponges, pads, other dressings	104,200,000
Sutures	136,300,000
Transfusion and blood donor supplies	85,000,000

Another factor that has added to the solid waste load, to a lesser extent, concerns the information systems that have mushroomed in hospitals. Use of paper in all shades and colors, often with disposable interleafed carbons, from simple requisitions, to photocopies of memos, letters, and reports, to computer print-outs, has grown by almost 500 percent in hospitals since 1950.

QUANTITIES OF HOSPITAL WASTE

Many statements have been made concerning the abnormally large quantity of solid wastes that hospitals generate compared to other institutions, to office and commercial buildings, and to residential complexes. A hospital is a community in itself; with a total population made up of patients, staff, and visitors. Hence, comparisons should be made between the hospital as a community, and a residential complex of similar size, to determine how valid has been the criticism that the hospital generates a far larger waste quantity than does a residential community of equal size.

The 1968 National Survey of Community Solid Waste Practices determined that residential complexes generate approximately 3.0 pounds, or 0.53 cubic feet, of waste daily per capita occupancy (or resident). It has been estimated that the average density of this raw waste is 170 pounds per cubic yard, or 6.3 pounds per cubic foot. (Compared with the average of hospital *raw* waste, as we shall see from figures given later, this is extremely dense.) This waste includes yard cuttings and trash, as well as all waste generated indoors.

It has also been estimated that between 1968 and 1974, residential waste has increased approximately 4 percent per year. If this holds, then currently residences are generating an average of 3.7 pounds per resident. This would be made up of yard cuttings and outside waste amounting to 0.8 pounds and a balance from building interiors of 2.9 pounds. The interior waste, which would be comparable to that generated by a hospital in this current study, can be defined, using the classifications issued by the American Public Works Association (APWA), as "garbage" and "rubbish or mixed refuse." The make-up would be 0.5 pounds of "garbage" (waste generated in the preparation, cooking, and serving of food) and 2.4 pounds of "rubbish or mixed refuse" (paper, cardboard, cartons; wood, boxes, excelsior; plastics; rags, cloth, bedding; leather; rubber; metals, tin cans, foil; dirt and dust; glass, bottles; stones, brick, ceramic, crockery; and other mineral products).

When we refer to "solid waste" in hospitals in the present study, we mean exactly that. Studies have been made in this field in which "soiled reusables" (such as soiled laundry, soiled utensils and dishes, or soiled patient items from bedpans to treatment equipment) were included in the total waste. We do not believe an item can be classified as "waste" that will be cleaned, and possibly sanitized or sterilized, and then reissued for further use. "Waste," for the purpose of this study, is material that will no longer be used, but will be discarded, presumably moved off-site, and presumably will be destroyed (or at least drastically modified in a recycling process). The definition of "solid" is that it has insufficient liquid content to be free flowing at room temperature.

The exact quantity of solid wastes being generated by the 7,061 A.H.A. registered hospitals in 1974 has been a matter of considerable discussion and disagreement among researchers. Surveys have been limited in any study to less than a dozen hospitals. Different surveys have included or omitted various materials in their definition of "hospital solid waste" and most comparisons have been of the "apples to oranges" type.

The research team that performed the present study has reviewed, to the best of our knowledge, virtually every article that has been published in technical journals on this subject over the past ten years and has reviewed copies of several studies, both published and unpublished, that have been performed by governmental agencies, hospital personnel, independent researchers, and other consulting groups.

From this material, we can at least state that the general consensus of opinion is that during the last 20 years hospital solid waste has experienced over a threefold increase. Various surveys that have been made would indicate that in 1950 hospitals generated approximately three pounds of solid waste per day for each of the 1,253,000 inpatients being cared for, or a total of 3,760,000 pounds per day. Continuing research over the years on the growth of the hospital solid waste load would indicate that the current figure is over 10.0 pounds of solid waste for each of the 1,209,000 inpatients. A total current waste load of 12,000,000 pounds for all of America's hospitals appears to be a reasonable figure from the information that is available.

Viewing hospitals as a community, consisting of inpatients, outpatients, staff, and visitors, the permanent 24-hour population in 1974, exclusive of visitors, would total 4,600,000 people. This would mean that the hospital industry is generating over 2.6 pounds of solid waste for each member of the hospital community. This is not too far from the current estimate of 2.9 pounds per resident for interior waste from other communities.

ENVIRONMENTAL PROBLEMS FROM HOSPITAL WASTES

INFECTIOUS WASTES

Solid wastes generated by hospitals are not in exactly the same category as those generated by homes or other dwelling units. While the total of hospital solid waste appears to be only in the neighborhood of 6,000 tons per day, and therefore less than 2 percent of the total solid waste load of the nation, from a biological hazard viewpoint, hospital wastes contain a certain amount of materials not normally found in other institutional or home wastes.

In any discussion of biological hazards, the words "concentration" and "dilution" immediately arise. The spread of disease among humans is caused by contact between the human system and the various bacteria or viruses that are inimicable to the system. This contact may be by direct touch or through the air, the water, or the soil. If the bacteria or viruses are diluted in a large field, the chances of entering and affecting the human host are considerably lessened. If they are both virulent and concentrated, the chances for spread of disease are strengthened.

Some investigators have stated that the type and concentration of bacteria and viruses found in hospital solid waste are little different from that found in the wastes generated from dwelling units, offices, factories, and other institutions of this country. Other researchers have given a completely opposite view and stated that hospital wastes may be potentially dangerous to the environment due to their "infectious" content. Unfortunately, the very few surveys that have been made (our own included) are inconclusive. Up to the present, no large-scale surveys have been made--either "in-house" or off-site at landfills--to prove or disprove the biological hazards of hospital wastes.

Theoretically, the difference between the biological hazards of waste generated in hospitals, with their population of "sick" people, and the waste generated by dwelling units and other buildings that are occupied basically by "well" people, lies in the concentration factor. A proportion of the waste materials generated by hospitals in the treatment of patients has been exposed directly or indirectly to various bacteria in a fairly concentrated form. From 2 to 8 percent of hospital wastes consist of such materials as: dressings for wounds, incisions, and burns; plaster casts; infectious laboratory samples; bacteriological cultures and media; pathological specimens; animal remains and biological specimens; body fluids and secretions, blood, urine, feces, and tissues; needles and syringes; disposable treatment devices in plastic, metal, and glass; "sharps"; newborn, pediatric, and geriatric diapers; and various contaminated disposable containers.

While such materials may represent only a small percent of the total hospital waste load, it it known from observation of waste handling practices that these potentially infectious items are not completely isolated from all other wastes in the hospital system. At some point, there is a reasonable possibility that these "infectious" wastes can be intermixed with other wastes.

The leading generation points for *known* infectious wastes are the surgical suites, the clinical and research laboratories, the research animal quarters, the autopsy suite and pathology laboratory, and the renal dialysis department. As these wastes come from *specific departments or sources*, segregation of infectious waste is possible by handling *all* wastes from these particular areas as infectious. Another known generation point is any care and treatment area or room for a *known* infectious case--inpatient, outpatient, or emergency. Many hospitals have switched to the use of almost complete disposable care and treatment devices for such known cases. The waste load has risen accordingly.

Infectious hepatitis appears to be a possibility in the waste from a renal dialysis department. Hence, all waste from this area is regarded as suspect. In view of the highly infectious nature of this particular virus, it is suggested that any materials used in dialysis and around known hepatitis cases be handled with extreme care. One suggestion made is that if wastes from known cases of hepatitis (or other highly infectious bacteria or viruses) are being transported, that they be moved in a virtually "unbreakable or unrippable" bagging system. Further, that "needle sticking" of the waste handlers be absolutely prevented by the methods used. The expense of the containers should be secondary.

The major problems in isolating possibly "infectious" wastes arise from the general patient care and treatment areas, both inpatient and outpatient, where large numbers of patients are being cared for by nursing personnel and diagnosis is often incomplete at the time. It is in these areas that infection level of most waste is usually unknown.

It is the conclusion of the research team that conducted the present study of hospital wastes, that too many hospitals are attempting to classify their wastes into categories that may not be logical--such as "definitely infectious," "potentially infectious," or "safe," It is our feeling that *all* solid waste should be handled with good management practices, regardless of generation source, both with in-house and off-site methods and systems. By standardizing on well thought out and efficient waste handling methods, properly supervised and executed, for *all* wastes, not only will financial advantages be achieved, but breaks in waste handling systems and resultant cross contamination should be greatly reduced.

External constraints have made the segregation of solid wastes extremely difficult, and hospitals have occasionally gone to extreme methods to solve these constraints. Burning known infectious material, along with the potentially infectious, in on-site incinerators, was a common practice until a few years ago. Today, with much more rigid air pollution codes and, in general, rather poor incinerator installations that are incapable of handling the large volumes of plastic used for disposables, hospitals have reduced the practice of bulk burning. An exception is the pathological waste, required to be incinerated by local regulation in most communities.

The majority of hospitals have turned to compacting their solid wastes to reduce hauling costs and contracting to have them hauled to a landfill or municipal incinerator. However, the nation is rapidly running out of sanitary landfill areas. Further, many such landfills are increasingly reluctant to accept hospital wastes for various reasons, ranging from potential effect on ground water, to dangers to personnel from the aerosols such waste may create.

In certain instances, hospitals have attempted to use germicidal sprays on a large scale in connection with their compaction of waste. In general, this has proven to be impractical due to the difficulty of penetration of the chemicals through the waste mass.

At least one major health department has objected to hospitals transporting wastes through city streets no matter how "sealed" the vehicle may be, or what precautions are taken, and this has put further constraint on the use of landfills or municipal burning.

In one community, hospitals have attempted to solve the problem by wet grinding of solid waste and flowing it into the sewer system. This procedure may or may not be practical. The opening of the waste grinder has been limited to no more than 9 in. by 6 in. to prevent overloading or overuse. This has involved considerable manual handling of the material, to the point of sorting and pre-crushing to fit the opening. The practice may involve risks to hospital personnel, plus potentially high labor cost to the hospitals. Grinding has also proven to have problems in maintenance of equipment, plus problems in flotation and sedimentation. With the sewer systems designed basically to accept food wastes, and with hospital waste consisting of as much as 80 percent in paper and plastic, external constraints have developed on the part of the sewer and sanitary departments, who are worried as to the effect on their systems should this practice spread.

As a last resort, faced with these various external and internal constraints, some hospitals have turned to investigating the possibilities of sterilizing their wastes from potentially infectious areas, before centrally collecting them and moving them off-site. Conventional steam and ethylene oxide gas autoclaves and industrial retorts have been used; bactericidal and sporicidal sprays have been tested. In addition, experiments have been conducted on sterilizing encapsulated waste within the plastic waste bags by ethylene oxide or formaldehyde pellets. Sterilization of waste has proven to be expensive, due to the difficulty in automating such a system compared to incineration, and has done nothing to reduce the total volume of waste for which the hospital must pay off-site hauling costs. Further, because of the labor, equipment, and supply costs involved, it has been limited to waste from known infectious cases and has offered no guarantee that the remaining wastes are "safe" to handle.

The consulting team in researching this present study was unable to locate much in definitive data from other surveys as to exactly what tests have been done on determining how "infectious" and how "hazardous" hospital waste actually is, day in and day out, across the board, and what actual effects this has had on the environment and human health. The bulk of the judgements that have been made in this connection have been based on the source of the waste and the conclusion that, if the waste came in contact with known organisms at the source, it was capable of retaining and transmitting these organisms.

Considering the number of hospitals and the number of patients being treated in the United States, surprisingly few studies have been conducted as to "*how* infectious" are these infectious wastes; and what type of bacteria are present in what levels. Some university hospital studies have shown pathogenic organisms present in the wastes, particularly if an organic substrate is present. Significant counts were made of coliforms, fecal streptococci, staphylococci, Candida albicans, and Pseudomonas. Bacillus organisms are most noticeable, particularly staphylococci and streptococci. With the amount of paper and cotton cloth in the waste, it is known that the mix is ideal for transmission of viruses, with a potential transmission time duration as long as 5 to 8 days. However, the studies have been on such a small scale as to not be useful when the conclusions are extended to all hospitals.

A literature review conducted by a commercial firm under an H.E.W. contract and completed in 1967, entitled "Solid Waste/Disease Relationships," did an extremely thorough survey of the research conducted to that year. A total of 755 references were analyzed, but the conclusions could only point out *suspected* disease pathways through solid waste systems. Opinion was expressed repeatedly as to the direct transmission effects between waste and disease, but, as the researchers for this report found, few solid facts were presented or conclusive proofs offered.

HAZARDOUS WASTES

Several researchers have stated that *all* hospital wastes should be regarded as "hazardous" when they are intermingled in a central collection point, in a compactor, or at a landfill. Infectious wastes are obviously hazardous in view of potential effects on handlers and the environment. However, in this section the term *hazardous* is used to denote wastes generated from hazardous materials: from any element, compound, or combination thereof, that is flammable, corrosive, detonable, toxic, radioactive, an oxidizer, or is highly reactive; and that in the process of handling, storing, processing, packaging, or transporting, may have detrimental effects upon personnel, equipment, or the environment.

In the total waste load of a hospital, the quantity of such materials is small--normally less than 2 percent of the volume. However, all such material requires special handling in transporting and disposal and hence can be one of the most expensive elements of in-hospital waste processing.

Radioactive materials are probably the best controlled of the hazardous hospital wastes. They may be in the form of radioactive liquids, containers, and disposable materials, animal carcasses, or tissues. Handling techniques vary between hospitals and with the radioactive substance. The most common method with liquids of relatively low level output is to dump the waste into the sewer system. Another method is to store both liquid and solid wastes in a secure area in containers with foot operated lids, allow the radioactivity to decay, then hand carry the waste through and out of the building. Other hospitals move the radioactive substances directly to the incinerator and burn them. Often this can result in high radioactivity in the ash; with some institutions storing ash for as much as three months to permit radioactive decay before burial. Other hospitals transport such wastes in sealed containers through the institution and bury it; in selected locations of their own; in municipal disposal sites; or ship it to one of the national disposal sites. The decay of radioactivity then takes place away from the hospital.

Chemical wastes form the bulk of the remaining hazardous wastes, with certain medicines and pharmaceutical products making up the remainder. These may be in liquid, powder, or solid form. The range of chemicals, solvents, and heavy metals is wide for potential effect on human beings, as well as on the hospital equipment and structure. They include strong acids and caustics of a highly corrosive nature; solvents in a wide range used from the laboratory to the maintenance department; compounds of mercury, arsenic, and cyanide, all highly poisonous. As much of the material is used in laboratory work and research activities in larger hospitals, as well as part of the workings of patient care and analytical apparatus, it becomes fairly wide spread through the institution. In many cases, it is in liquid form and the disposal method for a high percentage is into the sewer system. Recent OSHA regulations prohibit this practice for some chemicals. Some heavy metals, such as mercury, are subject in many hospitals to a reclamation program with varying degrees of success. Other liquid items generated in large quantities, such as certain solvents and acids, are transported in special canisters and then disposed of off-site, either buried, put into special wells or landfills, or shipped to reclamation centers.

TABLE 2

COMMON TOXIC CHEMICALS REQUIRING SPECIAL HANDLING IN HOSPITALS

- Boric acid
- Hydrochloric acid
- Nitric acid
- Orthophosphoric acid
- Phosphoric acid
- Potassium hydroxide
- Sodium hydroxide
- Sulfosalicylic acid
- Sulfuric acid
- Trichloroacetic acid
- Benzene
- Carbon disulfide
- Carbon tetrachloride
- Chloroform
- Copper sulfate
- Iodine crystals
- Mercury
- Phenol
- Potassium dichromate
- Potassium permanganate
- Silver nitrate
- Sodium dichromate
- Sodium floride
- Toluene
- Xylene
- Zinc chloride

PLASTICS

In the total make-up of hospital wastes, plastics of all types account for 11 to 20 percent of the total cube and from 5 to 12 percent of the total weight, depending on the hospital's supply practices in purchasing disposables. There are over 100 different uses of plastics in a hospital that relies heavily on disposables; and probably as many as 700 different formulations supplied among these. The soft plastics are used for packaging; drainage and intravenous tubing; containers; sheeting; waste bags; examining gloves; tape; surgical dressings and drapes; bed fabrics and clothing; masks. Hard plastics are used for bedside utensils; bottles; surgical and food trays; syringes; ash trays; containers; dishes and tableware; heart, lung, and dialysis machine parts. Various foams--mostly polyurethane and styrene--are used for heat-resisting cups and packaging materials. Among hospital wastes, plastics create unique disposal problems.

During incineration, plastics give off the most heat of any major classification in the waste, some exceeding 20,000 BTU per pound. This substantial heat can create breakdown of incinerator linings. In addition, the particulate emissions are considerable if flash burning occurs; as in the case of syringes (known as "syringe puff"). Flash burning can make it difficult to control the burning rate, which is essential in order to ensure that on a regular basis combustion contaminants remain at or below 0.1 grains of particulates per cubic foot of gas calculated to 12 percent of CO_2 at standard conditions.

It will be noted that polyethylene is one of the plastics that under combustion generates an extremely high BTU output. It is one of the most widely used plastic materials, accounting for 30 percent of total production. All of the plastics will burn at 350 F to 450 F, but to be incinerated in a smokeless and nearly contamination-free fashion, the combustion temperatures must be 1,800 F to 2,000 F for many common formulations. In many conventional incinerators, the introduction of plastics to combustion chambers that are not preheated has merely melted the plastic, clogged the grates, and deposited molten puddles which burn erratically and even explosively.

TABLE 3

INCINERATION OF PLASTICS

Type of Plastic	Heat of Combustion cal/gram	BTU/lb	Specific Heat cal/°C/gram
Polyvinyl chloride	7,040	13,700	0.35
Polyurethane	9,050	17,600	0.45
Polystyrene foam	7,040	13,700	0.35
Polypropylene	10,100	19,600	0.50
Polyethylene	11,064	21,600	0.55
Nylon	8,050	15,700	0.40
Vinyl	8,050	15,700	0.40
Acrylic	7,040	13,700	0.35

Destruction of certain plastics by burning releases corrosive chemicals into the exhaust gases. Polyvinyl chloride when burned gives off hydrogen chloride gas, which is toxic to humans. In a post-incinerator scrubber this forms hydrochloric acid and the effluent water must be neutralized. Additionally, the polyvinyl chlorides have a corrosive effect on incinerator grates and other metals as well as incinerator firewalls. Iron smokestacks will collapse after continued large scale burning of many plastics, since the resultant gas penetrates and eats the iron in an action similar to etching.

Plastics are not biodegradable in the same manner as animal and vegetable substances. One of the prime reasons for their popularity is that they are durable and offer long-lasting protection. If taken to a sanitary landfill, their life can be many years. None of the plastics commonly used in hospitals are broken down in the short run by weak acids or weak alkalines of the type which might be encountered in a landfill; they are extremely resistant to attack by bacteria and fungi. While not immune to ultraviolet in sunlight, the attack is slow and affects only the surface of the plastic. Some of the plastics--notably polystyrene--have poor weatherability, but none of them degrade completely. There is a form of advantage in this to the landfill.

Since virtually all plastics are essentially nonbiodegradable materials, they do not contribute to the pollution of ground water or evolution of gases.

They may, however, in certain physical forms, introduce special problems in landfills because they are difficult to compact efficiently, due to their resiliency, with ordinary equipment such as tractors, drag-lines, or steel-wheeled compactors. Plastic films, sheets, and bags tend to become entangled in the treads, wheels, and radiators of spreading and compacting equipment.

Because plastics are not readily biodegradable, composting has no effect on them. If plastic wastes are introduced into sewage treatment systems, they create problems. Sewage treatment plants are designed to handle basically biodegradable animal and vegetable products. Not only are many sewer systems already overtaxed, but also waste water is often reclaimed and reused and the danger of chemical contamination could be present.

From the above remarks, it is apparent that the advantages of plastics to hospitals for the fabrication of disposables and for packaging may be self-defeating. Each year during the past 10 years, the purchase of plastics by hospitals has increased at a rate of approximately 20 percent, in each case replacing an item made of paper, glass, metal, rubber, or a textile made from animal or vegetable fibers. In most cases, the plastic use has been in high volume, as it represents a disposable item that replaces a reusable item.

Long before the current energy crisis affected the production of plastics, many hospitals decided that they had reached the point of no return in the purchase of plastics. With the current converting of hospitals to reusable items, the ever-rising plastic purchase curve may commence to level off, or actually decline. Recent surveys by the study team have shown that several large hospitals feel that the most successful way they can combat their present solid waste problems is to greatly reduce purchasing of disposables. In order to reduce labor costs, at least 70 large hospitals have spent large sums on automating and mechanizing their processing departments, such as Pharmacy, Central Sterile Supply, Medical Records, and Dietary, and embarked on a serious return to reprocessing reusables manufactured from glass, metal, and other "permanent" materials.

HOSPITAL WASTE MANAGEMENT PATTERNS

The management of solid waste in hospitals has greatly improved during the past 20 years. It has also become much more expensive in personnel, supplies, and equipment that are used.

Any visitor to a hospital quickly learns that he is viewing a complicated and interrelated set of work procedures in which peaks and valleys are very evident. A hospital is a structured environment which (though many patients may not like to admit it) is designed to give efficiency to the medical and surgical care being rendered. There are early and mid-morning peaks in work loads ranging from giving patients baths, to readying them for medical and surgical procedures, to tidying nursing floors so that they give an uncluttered appearance to the patients and their visitors. Other peaks of activity are created by the serving of meals, given to most of the patients at their bedsides. There are also slack periods during which, in nursing wings, nothing appears to be happening except the updating of patient charts at the nursing station.

The ancillary and support departments are operated for the benefit of the medical team as well as the inpatients and outpatients. Surgeries have their peak periods during the morning and early afternoon hours. The laboratory and radiology find that the bulk of their work takes place during certain hours of the day, based on the time samples are collected or pictures made, in order to provide physicians and surgeons with diagnostic data within the time frame they have set. The kitchen and the food pantries on the floors are obviously tied in to meals, with hospital cafeterias often serving twice as many people at a sitting as there are inpatients in the hospital. Central sterile supply, the receiving department, and the warehouses must fit the routine of supply management in the institution, with peak times for breaking open cartons and issuing supplies and materials to the floors.

This routine of peaks and valleys has a definite effect on the way solid waste is managed in the average hospital. As mentioned, activity connected with the diagnosis, care, and treatment of patients involves people and it involves supplies, and these in turn generate solid waste in peaks and valleys throughout the 24 hour day over which all hospitals operate. In most hospitals successful waste management means concentrating on the peaks to eliminate them as rapidly as is practical.

PERSONNEL UTILIZATION

There appear to be two basic approaches in utilizing personnel for waste pick up and transport.

The first is known as "random" collection, in which a large number of the total staff each devote a percentage of their time to handling waste. For instance, during the day shift, the maids and porters from the housekeeping department clear waste from baskets in patients rooms, outpatient clinics, and from public areas. Assisting them may be the nurse aides who will also move waste; along with technicians in the laboratory, pharmacy, radiology, inhalation therapy, and central supply department; clerks and typists in the offices; and maintenance, engineering, supply, and laundry workers. Most of this personnel is not on duty during the evening shifts. During night hours waste pick-up is performed mainly by nurses aides from patient rooms and the Emergency clinics.

In each case the amount of handling of waste by an individual is relatively limited; consisting mainly of emptying baskets or other containers, normally in a bagged condition, and carrying the bags to a nearby collection room on the floor, or depositing the bags in the nearest vertical chute.

The total hours used by all this staff added together become quite substantial, even though the individual increments are in minutes. As a result of time and methods studies, many hospitals have switched partially or totally from the random collection system; and have set up one or more specialized waste handlers to cover the entire building.

On a "structured" system the maids and porters and possibly nurse aides may clear and bag waste from patient waste baskets and carry the bagged waste a distance of 50 to 70 feet to a nearby collection room, such as a soiled utility room on a nursing floor, or a chute room, where they will leave it for pick-up by specialized handler(s). The special waste handlers, from the housekeeping,or materials management department, will then pick up the bags and transport them vertically by chute or cart. Normally these handlers will also make "sweeps" of the building and clear all containers from support and ancillary areas and from all offices, public areas, and corridors. This is now the most common labor method used by hospitals.

Some hospitals have taken the system one step further and only the specialized handlers are permitted to remove and bag waste from any container or area of the hospital.

Time and cost studies have revealed that such specialization reduces the overall labor cost considerably and gives management a much tighter control over waste handling practices. If abnormal peaks develop in any area they can be handled quickly and as part of an entire, integrated system.

THE USE OF CONTAINERS IN WASTE HANDLING

During the past 20 years, hospitals have become sensitive to accusations that their environment is "germ laden" because of the sick patients and the potential "carriers" among the staff who are handling these patients. The outbreaks of staphylococcus in many hospitals a few years ago clearly revealed the contact problems that a hospital must face. More limited, less known, and much more deadly, have been problems with other bacteria and viruses, such as infectious hepatitis.

While American hospitals have installed the heaviest quantities of sterilizers to be found anywhere in the world, in order to rapidly kill bacteria present on supplies, material, and equipment, they have also learned that "sterile filth is no more desirable than unsterile filth." To maintain a properly controlled environment in a hospital, constant cleaning of almost everything is essential.

With research into aerosols and the effect of airborne contamination in hospitals, administrators have learned that open, overflowing waste baskets and trash cans cannot be permitted in a "clean" environment. It has been determined that solid waste in a hospital should be contained or encapsulated almost as quickly as it is generated and, secondly, that it should be removed as rapidly as possible from the nursing and support areas packaged in a bag durable enough to withstand transport. The number of waste baskets and trash containers has increased each year, with the galvanized metal container (with the lid missing) giving way to synthetic, rust-proof rubber created by industrial designers and with a lid that locks in place.

The number of plastic bags to line these containers has increased to the point where they are used almost universally in hospitals, adding to the increase of plastic in the waste stream. The bags are capable of sealing, self tying, or closing with twist wire bends, to provide a spill-proof, leak-proof containerization when transporting waste through the building. Only a few years ago the few that were used were usually of flimsy, clear plastic. Today such bags are available in a host of sizes, thicknesses, construction, and colors. Red bags are available for infectious waste; yellow for glass and metal cans; tan or clear to line waste baskets; black, white, or brown to hold other bags during transport; laminated bags or plain, straight sides or gusseted, with mil thicknesses from 1.5 to 10; even anti-static bags for use in surgeries.

THE ELEMENTS OF THE SOLID WASTE SYSTEM

Solid waste management in a hospital is a "stepped system." A series of operations follow in logical order, one step at a time.

The first step is to contain the waste intially, as it is generated, where it is generated. This normally involves discarding it into a nearby waste basket or trash can, which is usually lined with a plastic bag.

The second step is normally the initial horizontal transport of the bagged waste from the waste container to the initial collection point. This may be one of several locations. For example, the waste may be moved to a chute room or soiled utility room. Or it may be placed directly into a gravity chute and dropped to a collection room in the basement or first level. Or it may be picked up by a hauling cart and taken horizontally to an elevator, vertically to a lower level, and then horizontally to an intermediate collection area in the basement, or taken all the way to a final and central collection point. Or it may mean placing it in a pneumatic tube system for delivery to a central collection point.

The waste may be processed in some manner before it reaches the final and central collection point. It may be compacted on the floors before transport through the building. It may even be sterilized.

The third step is to move the waste from all the initial and intermediate collection points to a final and central collection point in the building or in an adjacent service building.

As the fourth step, all the assembled waste from all parts of the complex is usually processed in some manner. This may mean merely dumping it into an open hauling vehicle for off-site removal. More commonly it means compacting it in special equipment so that volume reduction is obtained. Or it may be incinerated. Or it may be shredded, pulverized, or milled.

The fifth step is to haul it off site, bagged, or as raw loose waste, or compacted, or ground, or milled, or in the form of ash residue.

AUTOMATION AND MECHANIZATION IN WASTE MANAGEMENT

The majority of hospitals transport solid waste within the building by hand methods, either hand carrying it in bags, or moving it by a pushed or pulled cart. These methods have been used in virtually the same manner since the first hospitals were formed.

While many hospitals have gravity chutes to transport waste vertically, hand methods must be used to carry or push the waste to the chute loading stations; and hand methods or carts must be used to carry the waste from the collection room at the bottom of the chute to some central collection point. Gravity trash chutes have created fire hazards in some hospitals. In the past few years, new fire codes, requiring better construction specifications, fire walls, and sprinkler systems, have obsoleted many existing chutes.

Many more hospitals have purchased mechanized *volume reduction* equipment than have purchased mechanization for waste *transportation*.

The first volume reduction equipment were the incinerators that virtually every hospital had installed by the 1920's. During the 1950's, wet grinders for garbage were installed in kitchens, serving the dual function of volume reduction as well as transport to the sewer line. During the past 10 years, as hauling costs have mounted, compactors have been purchased by over 40 percent of the hospitals, ranging in size from home-type units for installation on nursing floors and in ancillary departments, to heavy duty machines coupled to 40 cubic yard off-site waste hauling vehicles.

The most recent additions in mechanical equipment for volume reduction have been the shredders, attrition mills, hoggs, and dry grinders that a few hospitals have installed. These, like compactors, range from small, portable units for shredding office paper, to 3 ton per hour attrition mills installed at the central collection point and connected either to a compactor or an incinerator.

Less than 200 of the 7,000 hospitals in the United States have automated and mechanized the *transportation* of solid waste. Among these institutions a variety of methods are being used: including wet grinding or pulping; carrying in tote boxes on vertical and horizontal conveyors, or in dumb waiters; the use of automated carts, either controlled by electric circuits on the floor or suspended from overhead rails; the use of combination systems, with automation of the vertical movement (ranging from gravity chutes to automatic elevators) tied in with hand or cart movement for horizontal transportation in the lower levels.

A survey of over 100 hospitals that have already installed or are purchasing various types of automated transport systems for solid waste reveals that the installed cost ranges from $100,000 to over $1,000,000 for the equipment and space utilized. Only a small number of these institutions have employed the services of professional consultants and engineers, knowledgeable in solid waste management, and with in-depth experience in the design and feasibility of these expensive systems. In very few cases were intensive feasibility studies made of the volume of waste by specific generation points before the systems were designed. The location of sending stations, the routing of the system, and the design specifications were usually done by a system manufacturer and incorporated into the construction drawings by the architect.

Hospitals for the first time are studying in great depth the economic feasibility of such automation and mechanization. These studies are revealing that some of the directions that have been taken in the past have not resulted in operational savings. Caught in the squeeze between shrinking capital dollars for equipment and pressures to reduce operating costs, hospitals are learning the importance of feasibility studies, done professionally and done in depth, before embarking on expensive programs of automation.

With the external constraints and pressures on hospitals from local communities with regard to the off-site removal of waste, combined with the internal pressures, hospitals are also looking at another aspect of solid waste management; namely the possibility of drastically *reducing* the generation of waste in the first place. This involves their entire philosophy of operation. It particularly involves decisions concerning the purchase and use of disposables versus reprocessing medical and surgical supplies. Some hospitals that, up to two years ago, were heavy users of disposables have made abrupt changes in this direction. There are instances where the purchases of these items have been reduced by as much as 50 percent and replaced by reprocessed reusables. The effect on the total solid waste load has been dramatic, in some cases cutting the total cube by as much as 65 percent. A subsidiary effect has been a considerable reduction in operating budget, as these same hospitals are learning that intelligent, mechanized reprocessing is now also economically feasible.[9]

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2- ARCHITECTURAL DESIGN INFLUENCES

A modern hospital is probably the most complex institutional structure that has been designed in the Twentieth Century. The interrelationships between patient areas, both inpatient and ambulatory, and the ancillary and support departments run into the thousands. What is done in one function or area of the complex affects directly or indirectly dozens of other areas and functions. In the field of solid waste management, these complications are seen in every study performed in the past 20 years.

The architectural and engineering design of a hospital is always a compromise. There are over 100 major support systems involved, of which solid waste management, movement, disposal, and removal is only one. Within spaces that have often been likened to the "interior of a submarine," several support systems, often designed by several different disciplines, must fight for entrance and egress, routes, support lines from interfacing systems, and sheer space. The maze of pipes, wires, ducts, chases, etc., is thus a compromise and it is compromised still further by the installing trades and change orders during construction.

PLANNING SOLID WASTE TRANSPORT SYSTEMS

No hospital has yet been designed where the solid waste management system, whether it be pneumatic tube or other method, takes precedence over all else and thus has been able to obtain a "perfection in layout." Being a compromise, to fit with other systems into the structure, there are obviously built-in weaknesses in the system layout when superimposed on an architectural design.

Too often, a study of such systems reveals that the mechanical components are operating satisfactorily, and the human elements in operation and maintenance are doing exactly what they are supposed to do, yet the system is "weak" in one or more aspects of performance, due entirely to the architectural layout having compromised the system to too great a degree.

The installed systems usually do not operate at 100 percent efficiency unless they are planned on facts that are carefully assembled and then they are programmed to meet these facts. Good system design and layout cannot be "ivory towered." Architectural planning must move from being isolated at the drawing board to being married with industrial and management engineering. Before lines are drawn, and the fixed route, chutes, stations and collectors are positioned, what each must perform should be determined in detail, based on firm projections of the amount of waste (and laundry) that will be generated by each and every department and section of the hospital that must be serviced. Volume-use-time relationships must be established through a typical industrial engineering approach.

With an existing hospital, these facts are readily obtainable by the use of standard survey and statistical techniques in which all quantities, sources, and types of the waste being generated are carefully recorded. For new construction, projections have to be made based on figures obtained from hospitals of similar size, with similar programs, and in a similar zone of service. In both cases, operating projections for at least ten years must be made so that the systems are neither over- nor under-sized.

The parameters that must be developed before any systems can be planned and designed are the following:

1. What materials, defined as waste, must be managed, and what is their make-up from a variety of standards--e.g. combustible or non-combustible; "contaminated" or "safe," biological, infectious, hazardous, radioactive, toxic, or explosive; grindable or non-grindable (such as food wastes); dissolvable, or able to be slurried into a sewage system or wet pulping system; pathological and surgical, human and animal parts, and tissues; material make-up (paper, plastic, wood, metal, glass, ceramic, and textile).

2. What segregation, if any, of waste will be maintained, to separate the "problem" wastes from the so-called "safe" or general waste, and how practical is segregation, as well as alternate methods of handling the segregated wastes.

3. From whence will each type of waste be initially generated.

4. In what quantities (both weights and volumes), at each generation point, and at what times of day (peaks, valleys, and averages) will such waste be generated, by type.

5. From what points in the building, by what routes, to what points (interim as well as final) will all the different solid wastes have to be collected, packaged, moved, stored, collected again, reduced, and ultimately removed to some off-site location.

6. Due to either internal or external constrains, what time limitations may apply.

7. What safety regulations or limitations must or should be followed in handling and packaging these wastes for transportation within and away from the building.

Solid waste management is a "stepped system," and each step must lead logically to and be interfaced with the next step, so the result is one continuous flowing system without false breaks. To convert this to a hospital setting, it is essential that the following steps be studied, analyzed, and evaluated before the architectural design can be finalized:

1. How the waste will be initially deposited by the person or device generating it, and in what type of container (e.g. lined wastebasket or garbage can, closed or unclosed, mobile cart, or cloth bag), and in what location.

2. How the waste will be transported from this point, over what route, over what period of time, at what time, by whom, in what type of container, and by what method (cart or hand carried), to a waste chute or other removal method.

3. What temporary storage and/or processing will occur between initial generation points and the transporting of the waste (e.g. use of soiled utility rooms, floor storage rooms, corridor storage, autoclaving or melting, floor compacting, grinding, double bagging or special packaging, and/or labeling, etc.); what volumes and types will be involved, and over what time elements.

4. What transporting problems and times may be involved. This includes waiting times for access to elevators and waste chutes and the routes that

must be followed, to remove from the floor to a central collecting point.

5. If the waste is unloaded into an intermediate location, it must then be moved once more, either manually by cart, or by one of a number of available automated methods, to a central and final collection and/or reduction point.

6. From the central collection room, the waste may be transported into the final storage or reduction area. This can be located in a trash room inside the lower levels of the building; in a separate trash building; on, or adjacent to, the loading dock, incinerator room, or compactor area. Or some automation may occur, feeding directly into a hogg or grinder, then via a surge tank into an incinerator or compactor, or directly into a compactor and/or incinerator. Space for the various equipment items must be carefully planned.

7. Finally, there must be determined what volume reduction will occur in each step of the system "in the house," and how this affects the spaces planned for waste storage.

Solid wastes and their removal interface with the handling of the returns of soiled reusables for reprocessing, such as patient bedside utensils, medical-surgical reusable equipment and supplies, eating and drinking tableware and utensils, and both surgical and patient linens. Studies and analyses must clearly define these interfaces and how they affect and interact with the solid waste management.

Solid waste removal also interfaces and may affect clean material delivery and storage. Most hospital material consultants have for years preached the dangers of cross-contamination and the desirability of "clean" and "dirty" separation. This is basically a management engineering problem. The architectural design will obviously affect the problem and potential solutions tremendously. Some areas, such as surgical suites and laboratories, are often designed with "clean" and "dirty" corridors that establish a positive material flow to greatly reduce the problem. Other areas, such as kitchens, attempt to direct flow by equipment placement. Other areas, which are major solid waste generators, such as patient care and treatment departments, attempt to control the problem solely by personnel management and the introduction of "clean" and "soiled" utility rooms. However, the corridors, patient bedrooms, and treatment rooms are simultaneously used for the transportation of both soiled and clean items. Cross-contamination is a real possibility.

THE VERTICAL CHUTE--PNEUMATIC TUBE SYSTEM FOR SOLID WASTE TRANSPORT

The principle of pneumatic waste transport systems is a simple one, very similar to a large size vacuum cleaner, combined with a fixture that high-rise buildings have had for many years--the gravity drop, vertical trash chute.

To implement the system, one or more vertical waste chutes are installed in the hospital, with openings installed in them on each floor being serviced. These openings are the "loading stations" of the system. They receive solid waste, normally contained in plastic bags sized to fit the diameter of the chute. The loading stations are similar in appearance to those in standard gravity chutes. In one system they are almost identical to these, as modified gravity chutes are used for the vertical drop. In other systems they are sophisticated by the inclusion of a hopper that has an outer door for the use of the operator in loading the waste, and an inner door that opens on a timed cycle to permit the bag to drop into the chute.

At the bottom of the chute is a connection to a tube of identical diameter that pneumatically carries the waste horizontally through the hospital and finally deposits it in a box or tank known as a "collector." On a timed basis that is part of the total transport cycle, doors open in the base of the collector and drop the waste, by gravity, onto or into whatever is the next step in the process--a compactor, a cart, a dry grinder, a truck, or a trash room floor.

There are two basic system designs. One uses a gravity chute and the bagged waste drops down onto a plate or slide valve at the bottom. This plate cycles on a timed basis, opening to let the waste fall into a horizontal tube and an air stream that carries it to the collector box. This is known as a gravity to vacuum system. The other system uses a vacuum or air stream to pull the bag the entire route, from the loading station in the vertical chute to the collector box. This is known as a full vacuum system.

Both systems use large fans to pull the waste through the system, with the transport air allowed to enter the system at the opposite end to the fan. It is the velocity of the suction air stream that sets the speed at which the waste moves through the system. When the waste drops into the collector box, the suction air continues through a port in the box, and by more tubing, travels to the suction fan, and through it by an exhaust duct to the atmosphere.

SIZING THE SYSTEM

VERTICAL CHUTES

Based on chute loading surveys and time studies, it is obvious that selecting the proper number of loading stations and the proper location for each is not simple. We are dealing with a system of vertical chutes that are connected horizontally, at the bottom usually. While it is possible to lead the flow of material downward other than by a straight vertical drop, it complicates the installation of the system and increases the expense.

If the areas to be serviced are laid out identically and are stacked exactly one above the other in a high-rise structure, the installation of a straight vertical chute is *relatively* simple. It can go straight up through the middle of the heaviest activity, floor after floor. The loading stations will be stacked above each other on each floor for deposits into the chute.

With this situation there is still some flexibility of architectural design on each floor, as we are dealing with a round chute. It can be loaded from different directions on each floor, such as loading second floor from the north side of the chute, third floor from the south side, fourth floor from the west side, and so on. Hence, location and entrance into chute rooms can differ somewhat in the floor plans when stacking floors in an architectural design.

However, if in stacking, architecturally, one floor above the other, it is decided that the location of the chute loading stations will change horizontally from floor to floor, the design becomes complicated. If on second floor the chute loading station is to be next to the nursing station, and on the third floor this is still desired but the nursing station has been moved fifty feet to the west of the second floor location, and on fourth floor twenty feet to the east, we need a vertical connector between the three that must travel fifty feet horizontally on one floor and twenty feet on the other in order to link up. With a full vacuum system, this is possible, providing there is ceiling space for the tube. With a gravity drop system, it is out of the question.

It is obvious that, architecturally, the lower the height of the building or the less vertical drops required, the easier it is to design a system; the more important the horizontal runs become. However, as few one and two story hospitals are being constructed today, the designers have to worry about the vertical stacking problems.

LOADING STATIONS

To reduce the number of vertical chutes and loading stations to a minimum, designers should do extremely detailed analyses of the entire waste load of the building and then "zone" the entire complex, locating the vertical chutes and loading stations on a compromise basis. It would be impractical to have a chute loading station exactly where every small sub-section generating solid waste would like one. A rule of thumb is used that is based on walking time to load the chute. An area radiating out from the chute station between 70 and 100 feet is considered ideal to be serviced by the particular station.

To date, zoning on this basis has left something to be desired in any design we have studied. The simplest way to check this is to run a one-week survey, recording every bag that is deposited in every chute. A review of the chapter on volumes of waste generated shows that 90 percent of the total volume in any hospital is deposited in under 50 percent of the chute loading stations. This raises the question as to whether the remaining 50 percent of the chute loading stations were worth the expense of installing. How much did this virtually unused 50 percent of the stations cost? How many years of extra walking labor time to haul this 10 percent of the total waste to the other 50 percent of the stations would be involved before the extra stations pay for themselves?

Hence, in zoning a system, walking distance to the chute station must be factored mathematically with volume of waste generated within each zone, before a decision can be made whether a particular station should be installed. This, in turn, means virtually designing the operational procedures for waste collection before the system is designed.

Some basic facts are known in any hospital as to where the *greatest* volumes of solid waste are generated and over what periods of time during the day and what the make-up is.

On the basis of weight, as can be seen from the chapter on volumes and types of hospital waste generated, from 10 percent to 20 percent cannot be deposited easily in a pneumatic chute and tube system as they are currently constructed. The size of the waste pieces defeats the ability to load into the chute. Typical examples are large cardboard cartons, construction materials, crating and packing materials, iron pipe, large metal drums, etc. If these items end up on the floors of the hospital, they will have to be hand trucked to the central collection point. Certain other items, either liquid or solid, should not be loaded because of their hazardous nature; such as highly corrosive, explosive, inflammable, or radioactive materials. These may be 1/2 percent of the total waste. Other items possibly should not be sent through the chutes, unless they are packaged in spill-proof, unbreakable containers; such as highly infectious fomites, laboratory samples, and pathological specimens. These may be as much as 4 percent of the total load.

The remaining 75 percent to 90 percent of the total waste generated by the hospital could be transported by the chute system and the generation points, times, and material make-up are known for all hospitals in a general way. Past studies have shown that 80 percent of the total is generated by 20 percent of the departments, with surgery, dietary, nursing stations, maternity, laboratories, and the computer department leading the way. This overall data can be refined in an existing hospital or projected with comparative studies for a new hospital.

From this, a grid can be made for each floor on a zoned basis, as we have described, and the vertical chutes and desired loading stations overlaid on the architectural plan. Hopefully, with a building in the design stage, the architect and owner will agree to permit the vertical risers to be placed in the proper locations. With an existing building, the placement will depend on finding a clear vertical route or shaft (duct shaft, elevator shaft, etc.); even to the point of placing it external to the building, because there is no way to put it through internally.

CHUTE LOADING ROOMS

It is essential for the owner to realize that the architect must enclose the vertical chute in a fire-rated shaft. With its installation, a chimney has been added to the building that could spread a fire in the lower part of the building upwards. This takes up space and must be allowed for. The latest thinking is that the chute loading room and the chute should be a complete, fire-rated envelope, with the chute rooms sprinkled, because of the possibility of storing trash in them while waiting to load a chute.

This raises the question of how large a chute loading area should be. Until a few years ago, when gravity trash and laundry chutes were installed the loading doors could be in an open corridor or an open alcove. Modern codes prohibit this and call for a room in which to load the chutes, and normally with a fire-rated door. With a gravity to vacuum system, there should be no delay in loading the chutes. The chute loading room should be only large enough to: comfortably carry the waste bags into the room; comfortably maneuver the cart or other conveyance being used to carry the bags; and allow the room door to open and close without getting in the way of loading or cart maneuvering.

With a full vacuum single bag system, as will be seen, there is often waiting time to load the chutes. Aides, nurses, maids, and porters may refuse to wait; also such delays are expensive in labor wasted. Administration at the same time wants the patient rooms, nursing stations, support areas, and corridors clear of waste and soiled laundry and wants to prevent cross-contamination between the soiled and clean supplies. The dilemma arises--

where to temporarily store the waste and laundry until it can go down the chute. And secondly, what quantity will be involved at any point in time. While admittedly temporarily storing waste bags and laundry bags in the chute room is not good practice, it is better than storing them in the adjacent hallways. With a full vacuum system, that cycles slowly and accepts only one bag at a time, in peak periods some such storage will be necessary. The rule of thumb that has developed is to allow enough floor space in the chute room to hold a cart capable of holding 12 bags. This means a chute room at least 45 square feet in size.

FAN ROOM

The main architectural requirements are sufficient space to hold and be able to easily maintain the installed equipment; sufficient strength of floor to hold the heavy fan and motor without transmitting vibration into the surrounding area; sufficiently thick walls to prevent transmission of sound outside the room; adequate space and air flow to keep the room and its equipment cool; proper location in the complex so that the effluent air from the fan can be exhausted without affecting the environment.

There is no fixed rule as to where the room should be located in the complex as long as the above criteria are met. In general, fan rooms are installed on a roof area or on ground level.

CONTROL CENTER

Architecturally, the optimum location for this area is in the general location of other control engineering centers in the hospital. In the vicinity of the Engineer's office is the probable location.

COLLECTOR BOXES

A major weakness in many hospitals is that they have too small an area for a loading dock and receiving section. With a pneumatic tube system, this area must be large enough to fulfill its function.

If the hospital has an in-house laundry, the soiled laundry collector box will be installed in the soiled section of the laundry and should have a receiving and sorting area under it of at least 120 square feet.

If the laundry is remote from the hospital, the most protection from theft and the least labor in handling at the end of the line, is to construct a truck well, with a protective and locked fence around it and load an open-top truck or trailer at this location. The linen collector would be placed above the open trailer. Hence, at least 15 feet total head height would be required from base of well to top of collector.

The trash collector should be placed where it can be most directly fed into the collection and reduction equipment that will be used. This also infers providing sufficient vertical height and floor space to accommodate all the necessary equipment. This also infers that the location is easily available to hauling trucks for removal of loose or compacted waste or incinerator ashes. This can be an area adjacent to the hospital loading dock, a separate dock area, or in a separate service building.

If the collector is to discharge directly into a compactor-hauling bin asembly, a minimum of 14 feet head height and a minimum floor area of 12 ft by 15 ft is required for the compactor, plus space for the placement of the receiving-hauling bin.

If the collector is to discharge into an attrition mill or hogg, with a cyclone-surge tank-filter assembly, the vertical space required is up to 21 ft. Often, the hogg is recessed into an 8 ft deep pit to reduce floor level height problems as well as reduce noise transmission. Floor space to provide proper maintenance room for this entire arrangement is a minimum of 20 ft by 30 ft. To this must be added the space required for a compactor and hauling bin or an incinerator following the surge tank. Hence, in total, 1,500 to 1,650 square feet of space may be required.

STRUCTURAL STRENGTHS FOR INSTALLING EQUIPMENT

The heaviest equipment is at the end of the line with items such as compactors, hoggs and attrition mills, surge tanks, and incinerators. Equally heavy, per square foot of floor space, are the heavy motors in the fan room. Next are the collector boxes, many of which are suspended from ceiling beams. All floor and ceiling loads should be calculated carefully to ensure there is sufficient structural support.

The chief architectural problem is to eliminate vibration, either within the tube system, or being transmitted as sound or noticeable structural vibrations. In the chapter on construction analysis, the importance of vibration isolation has been stressed. The importance of rigidly and strongly anchoring the pneumatic tube to the structure has also been shown. This infers concrete or other dense material capable of holding the mounting system.

GENERAL CONSIDERATIONS

When an analysis is performed of the *total* waste removal problem of a hospital, it is seen that a pneumatic chute and tube system does not solve all removal problems. Items that are too large for the chutes, or for one reason or another are considered too "hazardous" to send down the chutes, will still be transported manually from generation points to the central collection area.

Whether the material is bagged and sent down the chutes or is hand hauled in a cart of some type to the ground level, the importance of avoiding cross flows and cross-contamination between the transportation of solid waste and the transportation of soiled reusables for reprocessing and the transportation of clean supplies cannot be overstressed. This appears to be one of the major archiectural weaknesses discovered when an analysis is made of solid waste management in hospitals. The use of service corridors and service elevators for the movement of supplies and of solid wastes appears to have been installed in too few hospitals. Such corridors and elevators should not be available to patients and the general public, and should have limited use for the movement of staff. Too often, we see an elevator or a main corridor being used simultaneously for the transportation of a cart loaded with bags of solid waste, a patient being moved on a stretcher, several of the hospital staff, from nurses to porters, and a sprinkling of visitors. It would appear that more attention should be given in the designing of hospitals for clear separation of traffic flows, to avoid this situation. Further, conditions of this type usually create much extra waiting time in both the movement of supplies and the transportation of solid waste, increasing the operational costs to the hospital. This is particularly true when service elevators, reserved exclusively for supply movement, have not been included in a high-rise structure.

3 DESIGN AND CONSTRUCTION CONSIDERATIONS

The purpose for which pneumatic tube systems are used in hospitals is to transport safely and free of cross contamination, without plugging, or failure to move, loads of solid waste and soiled laundry. As it is possible for a transporting bag to break or spill in transit, this infers also the ability to transport loose particles of solid waste and loose textile items. These facts set certain limits and define certain standards for any such system.

It is impossible to study the existing systems with respect to the movement of solid waste only, as in many cases both soiled laundry and solid waste are transported in the same vertical chutes and pneumatic tubes. In other cases, they are in separate chutes and tubes but controlled by a common suction fan. The transporting of laundry affects the transporting of waste, and vice versa.

A review of these systems that have been installed in hospitals reveals a wide variation in design and construction standards, despite the fact that all such installations are supposed to perform almost identical tasks. A detailed analysis indicates that these variations in approach arose from the fact that the owners, the specifiers (architects, engineers, and consultants). and the vendors attempted in many cases to reduce the capital cost of the installed system, despite a potential for serious effects on operating costs during the first ten years of use.

SINGLE TUBE FULL VACUUM SYSTEMS

The first pneumatic transport design used in a hospital was a single tube system, to carry both solid waste and soiled laundry, and with a single fan at the end of the line to create the suction to carry the load through the system. This fan runs during the period of the day the system operates. There are separate loading stations throughout the complex for solid waste and for soiled laundry. These are normally in the same "soiled" collection room, and are adjacent to each other, leading into a common vertical riser or chute. When a chute loading door is opened it exposes a sloped hopper, or loading station, with an inner door leading to the vertical chute. The operator places a single bag of waste, or of soiled laundry, in the indicated (waste or laundry) hopper and closes the outer door. He then presses a button or turns a switch to activate the movement.

This creates a sequence of events. A roof damper opens to allow air to be sucked through the vertical chute involved and through to the exhauster fan. All other chute roof dampers remain closed. A damper over a continuous operating fan is raised, allowing the fan to suck in this air; or alternatively the suction fan starts up. After proper air flow is established in the system, the inner door of the loading hopper opens by a compressed air cylinder, allowing the bag of waste or laundry to drop into the vertical chute and into the suction of the air stream. Depending on whether the waste or laundry sequence has been activated by the operator, at some point in the system a "diverter" valve swings into the proper position to shunt the bag into the proper collector box at the end of the line--either waste or soiled laundry. After a timed delay to ensure the bag has dropped into the chute, the inner door of the station closes.

The bag travels the tube system and drops into the collector box. The effluent air stream that provides the suction continues out of a port in the box and travels by more tube to the fan; it continues through the fan and is exhausted to atmosphere. At this point the dampers all close. Based upon a prefigured time cycle, doors open in the bottom of the collector box and drop the bag out of it by gravity onto the floor, a cart, or whatever else is designed into the system beneath the box. The system is then ready to start over again and accept its next bag. In short, all such systems work on the same principle as a vacuum cleaner. They are called "full vacuum" systems, as the vacuum is pulled on the vertical risers, or chutes, as well as on all the horizontal tubing, creating a suction throughout every part of the system.

Such a "single tube" system obviously can create problems. Originally, some had only one loading door at each station with two activating switches to push--one marked "trash" and one marked "laundry." If the operator pushed the wrong switch, the diverter valve had no way of knowing this. Waste wound up with soiled laundry and vice versa. To prevent this, separate loading doors and hoppers were used--one for waste and one for laundry--each still leading into the common vertical chute, the separation being purely psychological.

However, human mistakes still could occur. Or, mechanical and electrical problems could develop, in which the diverters could be faulty and not divert as scheduled: again resulting in misdirected loads.

Another problem with "single tube" systems is that a bag of waste could break or spill in transit. When followed by a bag of laundry, particles of waste often ended up in the soiled laundry, the most common being broken glass.

It was also discovered that such single tube, full vacuum systems were rather slow. They were designed to carry a single bag in the system at a time, with a total cycle time, from the placing of the bag in the chute loading hopper to dropping out of the collector, as high as 40 seconds. This meant that less than two bags per minute could go through the system. The standard "push button" design ensures that the inner door of the loading hopper provides a positive seal or closure between the "soiled" chute room (and the loading hopper) and the vertical-horizontal pneumatic system. The inner door leading to the chute must be closed completely before the outer door of the loading hopper can be opened. This is accomplished by an electric or air-operated lock on the outer door. The purpose is to ensure that the system operates on "one bag at a time." Also that it does not draw air in from the chute room and hence change the basic balance of the vacuum pull for which it was designed. Such systems often have as many as 50 or more loading stations (divided between waste and laundry) and they cycle normally on a "first come-first served" basis, with relays activating the stations from a simple memory circuit.

Let us assume that, during the morning service peak, seven people decide to use the system, in various parts of the hospital, at the same time; and that each has up to five bags of laundry and three of waste to get rid of on this particular trip. Let us assume further that all seven operators load their first bag (waste or laundry) about the same time into the particular chute station they are using. Each also pushes his activating switch. The system cycles on a "priority load" basis through relays in the control panel. Each operator must wait until the system has cleared and the signal light on his door shows his first bag has been transported, so that he can load in his second bag, and so on for each successive bag. He waits his turn in line as the system cycles between stations. For each bag, he may be second in line or seventh.

Assuming a total of eight bags for each operator and seven stations being loaded simultaneously, this is a total of 56 bags being put into the system at a peak period. Assuming each bag takes as little as 30 seconds to travel its complete route, only two per minute can be transported in total. Hence, an operator could be waiting by his chute station for as long as 28 minutes until he could get rid of his last bag. Obviously, this is an unsatisfactory situation, as all seven people loading the chute would be in virtually this same position and approximately 7 x 28, or 196 minutes (over 3-1/4 manhours) of expensive labor would be used merely in waiting time to load only 56 bags into vertical chutes.

MULTIPLE LOADING FULL VACUUM SYSTEMS

To avoid this problem of holding people at chute loading doors while they hope their turn will come quickly, certain busy hospitals asked for a change in the loading sequence and cycling. They requested that the principle of one bag at a time in the system be eliminated. They insisted that the tube system be capable of hauling, in a single pull, a train of up to twelve bags at once. In a full vacuum system, this was called a "key-lock" method. Instead of pressing the "go" button, the operator turned a key to activate the switch. This overrode the system's normal cycling. As long as the key was "on," the inner door remained open, as did the fan damper and roof damper. In short, the vacuum remained on and pulled as many bags as the operator could drop in, one after another, or that the collector box at the end of the line would hold. To hold a succession of bags, the collector must be of larger size than for a single bag system. When the key was turned the other way, the collector box doors would open and drop the whole load of bags it held at the end of the line. Then the entire operation could be repeated at the same chute station or at a different station.

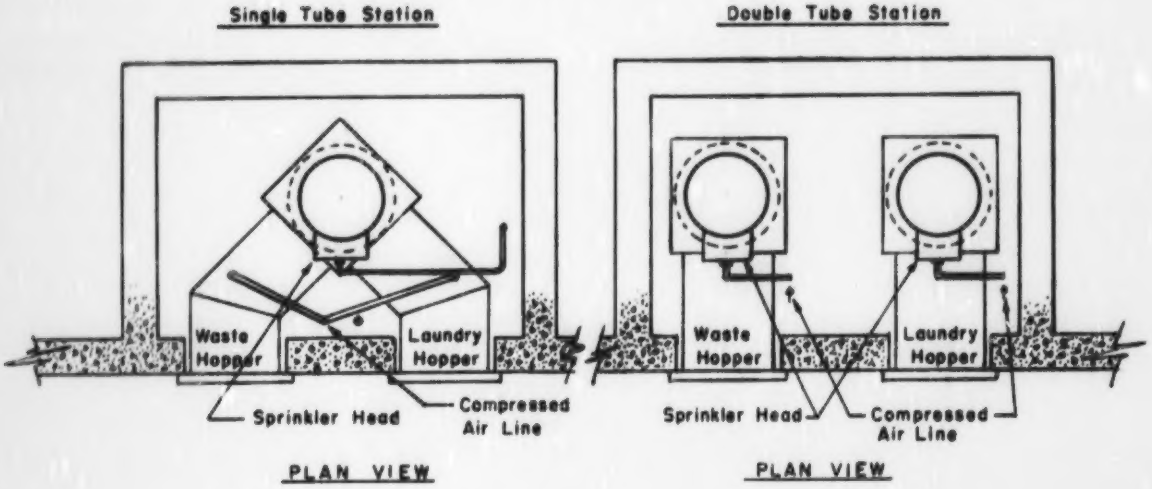
A difficulty in this is that only one operator can use the system at one time. When he is loading his door, all other doors lock closed automatically to avoid overloading the system with too many bags. Hence, it is normal for such a system to be used only by special operators, who travel from station to station and load out all the bags of waste (and laundry) that various other hospital personnel have deposited adjacent to the chute station. At least there is the labor advantage of only one individual engaged in waiting time, and that time is reduced by at least 75% through multiple loading.

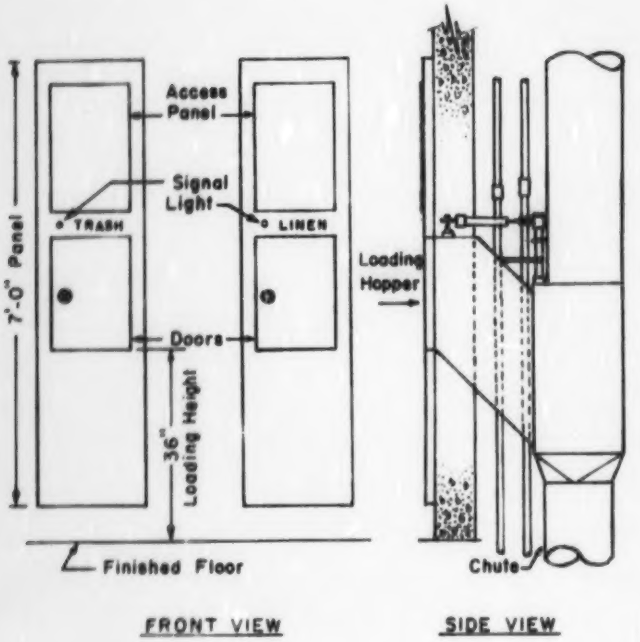
Further, this loading process has certain hazards. The operator is overriding a full vacuum system. Both inner and outer doors of the loading hopper remain open. While air to create the vacuum is being sucked from the roof vent at the top of the vertical chute, it is also being sucked by the fan from the open chute loading door. We have observed enough vacuum force to pull open the heavy door of the chute room itself and to require the operator to hold open the outer door of the chute station with the full weight of his body. A positive "open position" latch appears to be a necessity.

Another problem of the single chute system lies in the fact that it is used to carry completely dissimilar objects in a common tube. Laundry is normally sent through the system in cloth bags, packed rather full and weighing from 5 to 20 pounds each. Waste is usually in plastic bags with loaded weights of from 2 to 12 pounds. Yet the same tube and the same suction force or air velocity is required to carry this wide divergence in load in a single tube system.

DOUBLE TUBE FULL VACUUM SYSTEMS

Due to the problems described in the single tube full vacuum system, designers decided to sophisticate the construction of such systems, though it


Single Tube Station
Double Tube Station
Waste Hopper
Laundry Hopper
Sprinkler Head
Compressed Air Line
Waste Hopper
Laundry Hopper
Sprinkler Head
Compressed Air Line
PLAN VIEW
PLAN VIEW


Access Panel
Signal Light
TRASH
LINEN
Doors
7'-0" Panel
36" Loading Height
Finished Floor
Loading Hopper
Chute
FRONT VIEW
SIDE VIEW

These drawings show the various configurations used in loading the stations of the full vacuum systems. With a single tube station that accepts both solid waste and soiled laundry, many different configurations can be used to enter the loading hopper into the vertical chute. Close proximity of waste and laundry loading doors, despite clear markings for the material to be loaded, allows room for loading error by operators.

FIGURE 1. TYPICAL FULL VACUUM PNEUMATIC TUBE STATIONS FOR SOLID WASTE AND LAUNDRY

would increase the capital cost.

The first approach was to utilize separate tubes for waste and for laundry. Obviously, this would permit totally different construction specifications for each tube. At first a common fan was used to pull the air for both tubes and a common return air line led from the collector boxes to the fan. This still meant the systems had to cycle in the same manner as the single tube system, as the fans and the logic were not designed to operate both the waste and laundry systems simultaneously or independently. The latest systems are entirely independent and separate, each with its own fan, so that loading of either system does not affect the other. The double tube system utilizes either the push button, one bag at a time method, or the key-lock method for multiple loads.

GRAVITY CHUTES TO VACUUM SYSTEMS

It was also apparent that pneumatic tube systems for moving solid waste and/or soiled laundry have certain operational problems that must be solved in providing a satisfactory design.

The first problem already mentioned is the speed of removal of the solid waste or soiled laundry from the floor. The second problem is whether this has to be done by special personnel trained to load the chutes, or whether anyone, from janitor to nurse, can handle the task, and on a completely random basis; by merely coming up to any chute door, opening it, and depositing in the proper chute ("trash" or "laundry") as many bags at a time and at any time as is desired. Thirdly, to be economically feasible the system must move at least 95% of the total waste cube and weights safely and without any cross-contamination problems. There cannot be all sorts of exceptions as to the type of waste that cannot be sent through the system for fear of damage to either the system or the environment and thus must be hand-carried around the system.

A cursory examination of the "old fashioned" gravity chutes show they meet all the loading criteria we have mentioned. Anyone can load them at any time and as fast and as much as desired. And further, the loading can be in bags or as completely loose items. The only limitation on the load descending the chute is that is is small enough, or secure enough, not to lodge in the vertical chute. If it meets these requirements, gravity does the work and the load dumps out at the bottom. The mess often created at the bottom is another consideration altogether. It is off the upper floors of the building.

One of the systems studied takes advantage of this thinking. The vertical chutes are simply the "old fashioned" gravity chutes with separate chutes for solid waste and laundry. The chute doors and loading ramps inside them are similar to those found in other gravity chutes. Some additional features have been added. On the waste chutes, the loading door is slightly smaller than on the laundry chute. Normally, a rubber baffle is placed at the outer circumference of the vertical waste chute, at the end of the sloped loading hopper, to prevent any solid waste that may be descending from the floors above from flying into a chute station when it is being loaded. Further, a fan downstream in the system creates a slight negative pressure through the chute at all times by pulling 200 to 300 CFM of air. This prevents contaminated air from entering the loading station when the chute door is opened.

At the bottom of each vertical chute is a heavy steel plate termed a "slide valve." The solid waste or the laundry falls down the chute and lands on this plate, collecting vertically in the chute. On a predetermined time cycle (every few minutes) through the action of a pneumatic cylinder, the plates slide, or swing open, through the chute wall, one at a time, and drop the load each is holding into a short transition section below them. They then swing shut and the vertical chute is momentarily empty.

The chamber below the valve curves at the bottom into a horizontal tube of the same diameter on the downstream side; an inlet air line of like diameter enters on the upstream side. When the slide valve dumps its load down, the suction fan pulls the inlet air against the load, carries it into the horizontal tube and the suction air flow, to the collection terminal at the end of the system.

Discharge of the chute load is quite rapid (10 to 15 seconds). In the cycling, one chute at a time is discharged, starting at the downstream end, timed so that as one valve closes, the next valve opens, until the whole cycle (for all chutes) has been completed. Loads from two to three chutes may simultaneously travel in the tube to the collection terminal, if the cycling is programmed in this fashion to expedite movement. Normally the cycling is figured so that chutes are emptied when the storage load has reached a cubic yard. As the cycling can be pre-programmed by a time clock, the waste cycle and the laundry cycle do not have to be the same. For example, in peak periods the laundry chutes could be emptied twice as many times as the trash chutes.

It will be noted that this is entirely different from the "key-lock," full vacuum system described earlier. While the vacuum suction is pulling the waste or the laundry through the system, there is no vacuum being pulled on the vertical chute is a gravity-vacuum system. It remains a gravity chute, but with a negative pressure in it.

Such a system is not problem-free. A bag can break when it hits the slide valve after the vertical drop. Further, it can contain glass, other breakable objects, and liquids. Thus, the vacuum pull of such systems is designed so that it can move loose objects, such as broken glass; or it can move a "plug" such as a single bag or a train of several bags. Observations have been made of as many as 20 heavy laundry bags being moved simultaneously in this system. The surfaces of the slide valves are the main environmental hazard. They must be kept clean on a regular basis. This aspect is discussed in a later section.

These are "double tube" systems. With separate vertical chutes for waste and laundry, the vacuum, or pneumatic, horizontal tubes are also separate and usually constructed to entirely different specifications. Normally, the vacuum is supplied by a single fan for both the waste and laundry lines, on the theory that the system has enough storage capacity at the bottom of each gravity chute to permit a cycling sequence to take place over a period of several minutes without slowing down chute loading. A diverter valve switches the fan suction to the system (waste or laundry) being serviced in a particular cycle. A butterfly valve opens to let in inlet air. The exhauster fan starts and when full flow is reached the discharge valves open in sequence.

Such a system has much larger loads going through it at one time than the other systems described, in order to clear the deposits from the bottom of

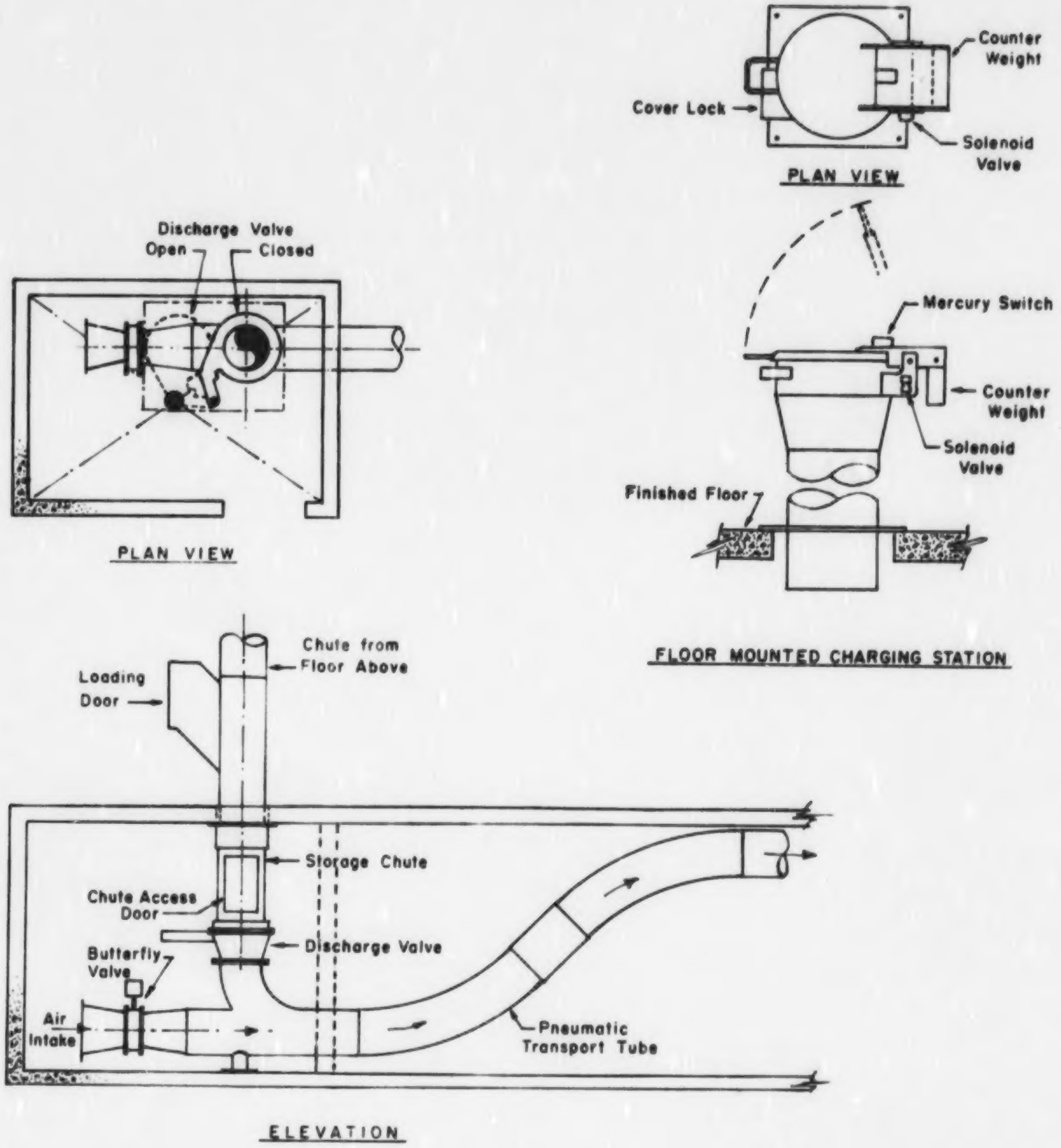

Counter Weight
Cover Lock
Solenoid Valve
PLAN VIEW
Discharge Valve
Open
Closed
PLAN VIEW
Mercury Switch
Counter Weight
Solenoid Valve
Finished Floor
FLOOR MOUNTED CHARGING STATION
Chute from Floor Above
Loading Door
Storage Chute
Chute Access Door
Discharge Valve
Butterfly Valve
Air Intake
Pneumatic Transport Tube
ELEVATION

FIGURE 2. GRAVITY-PNEUMATIC TRANSPORT SYSTEM SHOWING CHUTE STORAGE AND DISCHARGE VALVE

several gravity chutes during a complete cycle. Hence, the collectors at the end of the line are quite large, usually 3 cubic yards minimum, in order to hold these volumes. The system is fast, with a capability of transporting and collecting 24 cubic yards of waste or linen in one hour, in medium duty operation; or as much as 10 cubic yards in an 8 minute cycle in a heavy duty operation (the equivalent of 75 fully packed laundry bags of 3.6 cubic feet each).

SIZING OF THE CHUTES AND TUBE

After years of experimentation in hospitals, it has been determined that there are optimum handling sizes for bags of both solid waste and soiled laundry. The laundry comes from two main sources: the patient bed linen and surgical or treatment linen from O.B., O.R., and ancillary areas such as O.P.D., E.R., Radiology, I.C.U., Recovery, etc. The solid waste comes from a wider variety of sources, ranging from waste baskets in patient rooms, offices, and support departments; disposable drapes in O.R.; animal bedding in research facilities; cartons, packing and crating material, generated from incoming supplies and equipment; solution bottles found in certain treatment areas; snack bar, cafeteria, and kitchen containers, paper, cans, and bottles.

Is there a maximum and minimum weight and cube of these items, when bagged for ease of handling, as well as an ideal or optimum size load? Apparently there is, and several factors enter into the determination.

The first factor is convenience of deposit at the initial stage of waste generation. Over the years a variety of sizes of waste baskets and trash containers have developed in hospitals. They are designed to be of the proper cube to hold in an uncompressed form the amount of waste generated during a fixed period (8, 16, or 24 hours) in the area they serve: patients' room, office, public hall, snack bar, laboratory, utility room, etc. Secondly, they are designed to be loaded gently and by gravity, so that contamination of the surrounding area by aerosols, or contamination to the people doing the loading, is kept to a minimum, without shoving and stuffing, without spillages outside the container.

With the advent of disposable plastic bags, hospitals started buying these in large quantities to line their waste containers. The theory was that this further reduced aerosols and waste handling. Once the container was filled, or partially so, the entire bag load could be removed and taken away in a closed condition for disposal. This brought in another consideration for sizing containers. These bags used for liners had to hold a convenient amount in both weight and cube that one individual could easily lift out and carry to some place for disposal.

Obviously, there should be direct engineering relationships between the diameter of the tubes in any pneumatic solid waste movement system, and the suction power of the air stream, versus the size or cube of containers and loaded waste bags, and the weight of an average bag, and the number of bags that must be moved at one time. Too often we have discovered the two sets of considerations appear to have little connection with each other in the systems that have been installed.

Under the National Fire Prevention Association's Code, Section 82, gravity waste chutes in a hospital must be 24 in. in diameter in order to take the bulk of the waste sent down them. This will be discussed further in the section on codes and regulations. Pneumatic systems in hospitals have not been constructed to this size, as it was felt they would be too expensive to install. The bulk of the pneumatic transport system chutes and tubes are 16 in. in diameter, some are 18 in. in diameter, a few are 20 in. in diameter. The NFPA Code states that 16 in. should be "a minimum."

How does this compare with the size of waste loads that are generated and the waste container liners in use in the various hospital departments?

On an average, waste baskets in patient rooms and in offices measure 11 in. to 14 in. in diameter by 13 in. to 17 in. deep. The average flat dimensions of the liner bags are 22 in. wide by 22 in. long. Bulk trash containers vary considerably in size, depending on the location being serviced. The largest are found in public areas, animal research quarters when bedding is dumped, vending machine and snack bar locations, and in kitchens, where containers up to the size of a 44 gallon garbage can are used, with bag liners up to 36 in. wide by 52 in. long in flat dimension, fitting into these bulk containers as large as 22 in. diameter by 24 in. high.

If the pneumatic chutes and tube system are to be used to remove solid waste from all sections of the hospital, the containers and bag liners must be sized to match the tubes. For such an expensive, automated system to be self liquidating and economically feasible in labor saving cost, it must carry at least 95 percent of the total solid waste generated. This is discussed in depth in the section on economics.

The containers and bag liners used for initially depositing the solid waste cannot be larger than will go in the chutes. It is both a bad sanitation practice and wasteful of labor to have to break down by hand into smaller bags the waste collected in the initial deposit containers so they will fit the chutes. Alternatively, the chutes and tube system should be capable of moving groups of smaller bags such as are found in half-filled waste baskets, or these can be placed in a larger "chute transport" bag. If there is such a thing as an "average" trash chute bag, it would be a plastic bag, 34 in. long by 24 in. wide (flat), which stuffed full and tied would be approximately 15 in. in diameter by 25 in. long, and weigh, loaded, 4 to 14 lb, depending on the make-up of this waste.

Hence, there is a minimum size of chute and tube that should be installed and a maximum size of waste container and bag that should be used, if the hospital is to have a complete system from start to finish. It is now generally agreed that pneumatic tubes should be at least 18 in. diameter for optimum loading of bagged waste, and that 16 in. diameter is on the borderline as a minimum size.

Laundry is generated in different bulk and weight than waste; usually in larger unit quantities, and for this reason alone it is most difficult to use the same chute and tube to carry both laundry and waste successfully. Laundry from patients' rooms breaks down satisfactorily into a bundle for a complete bed change, along with towels and gowns, for two patients. This weighs on an average 8.5 lb dry and up to 10.0 lb damp, and it fills a flat cloth bag 32 in. long by 23 in. wide, ending up as a bagged load 15 in. in diameter by 26 in. long. Other typical patient linen loads (gowns, towels, sheets) weigh 5.0 to

15.0 lb in such a bag. O.R. linen and treatment linen from single procedures is much larger in bulk and weight, with the "average" size bagged bundle 17 in. in diameter by 30 in. long, weighing up to 20 lb in damp condition. For this possibly contaminated laundry, a large hamper bag with flat dimensions of 27 in. wide by 38 in. long keeps the "stuffing," and possible spread of aerosols, to a minimum. It is thus seen that the pneumatic laundry tubes are more efficient if they are slightly larger than the trash tubes. The preferred size for maximum efficiency is 20 in. in diameter.

STRENGTH OF CHUTES AND TUBE

Having determined the ideal diameter of the tube for the system, along with the maximum weight to be moved in horizontal runs and upward slopes, it is then necessary to determine the suction or air flow required to pull the heaviest permissible load over the planned distance of the system, at the speed required to safely move the load. Suction, vacuum, volume, and speed of air flow are used more or less interchangeably by engineers designing these systems. Regardless of the terms used, there is another direct engineering relationship. It exists between the diameter of the chutes and tube against the amount of vacuum being exerted for the weight of the load being pulled. This determines the required wall strength of the chutes, tube, and fittings, the strength and rigidity of the couplings, and the strength of the hangers by which the chutes and tubes and mounted to the building.

The original 16 in. diameter chutes and tubes were made from 20 gauge mild steel, either plain, or galvanized to prevent rust. This is fairly thin metal. The tubes were formed in sheet metal rolls by the manufacturers and then lock-seamed for the entire length. The ends were flared outward, and over each was slipped a large, flat ring. The next tube was butted to the first and a second ring, or flange, placed on it. With a gasket between the flanges, they were drawn together by up to 15 bolts and nuts all around, thus securing the joining of the two tubes. The elbows, Ys, tees, and other shapes that were used to change direction from the straight runs, were also made of light 20 gauge sheet metal and were usually square rather than round in cross section, for ease of fabrication. The tubes were hung from ceilings or slabs by threaded bolts, usually into concrete.

This light sheet metal can create problems when a pneumatic system is used under heavy loads. The major problem is collapsing of the tube or fittings when excess vacuum is pulled on them. The chief cause of such excess vacuum is the plugging of a tube by bags getting lodged at some point and the fan continuing to pull against the plug. From the figures given previously, it can be seen that on the full vacuum, single bag systems the heaviest weight to be pulled in a 16 in. chute could be a 15 lb bag of uncompacted waste, or a laundry bag weighing 18 lb. In an 18 in. chute. the weights could increase to 17.5 and 20 lb respectively as the bag diameters are increased from 15 in. to 17 in. In a key-lock multiple loading system, with 12 bags in a train, the average total weight being pulled could amount to 108 pounds of waste and 180 pounds of laundry in a 16 in. system and up to 140 pounds of waste and 220 pounds of laundry in an 18 in. system, based on average weights transported.

These figures indicate that over a 7 year period, averaging 6 hours use per day, the fatigue point of the metal would be reached if 20 gauge steel were used in a 16" diameter single bag system. With a multiple bag system, 16" diameter, this fatigue point would apply to 18 gauge. In an 18" diameter system, the same condition would apply to 16 gauge and 14 gauge steel respectively.

To give some engineering figures on vacuum being pulled in these systems and speed of air travel, we find that air travel speeds range from 50 feet per second to 100 feet per second at the maximum with 80 feet per second probably an average. The lowest air speed permissible to move a medium sized waste bag has been calculated at 15 feet per second. To convert these to vacuum, we find that while many of the fans can pull 9 in. Hg, the average system operates around 5 in. Hg, with fan cut offs at around 6 in. Hg. It has been calculated a bag would move and the system could clear at as low as 1.0 PSIg.

This has led to three developments in installing such systems. First, maximum vacuum pressure for the system is established by the engineers or

Comparing the three commonly used tube diameters with (1) potential wall thicknesses (metal gauge) and (2) potential vacuum or pressure that can occur in pneumatic transport, the accompanying curves indicate that to withstand the average maximum 4.4 P.S.I. system pressure, a 20" tube should be constructed of 13 ga. metal or heavier; 18" tube of 14 ga. or heavier; and 16" tube of 15 ga. metal or heavier.

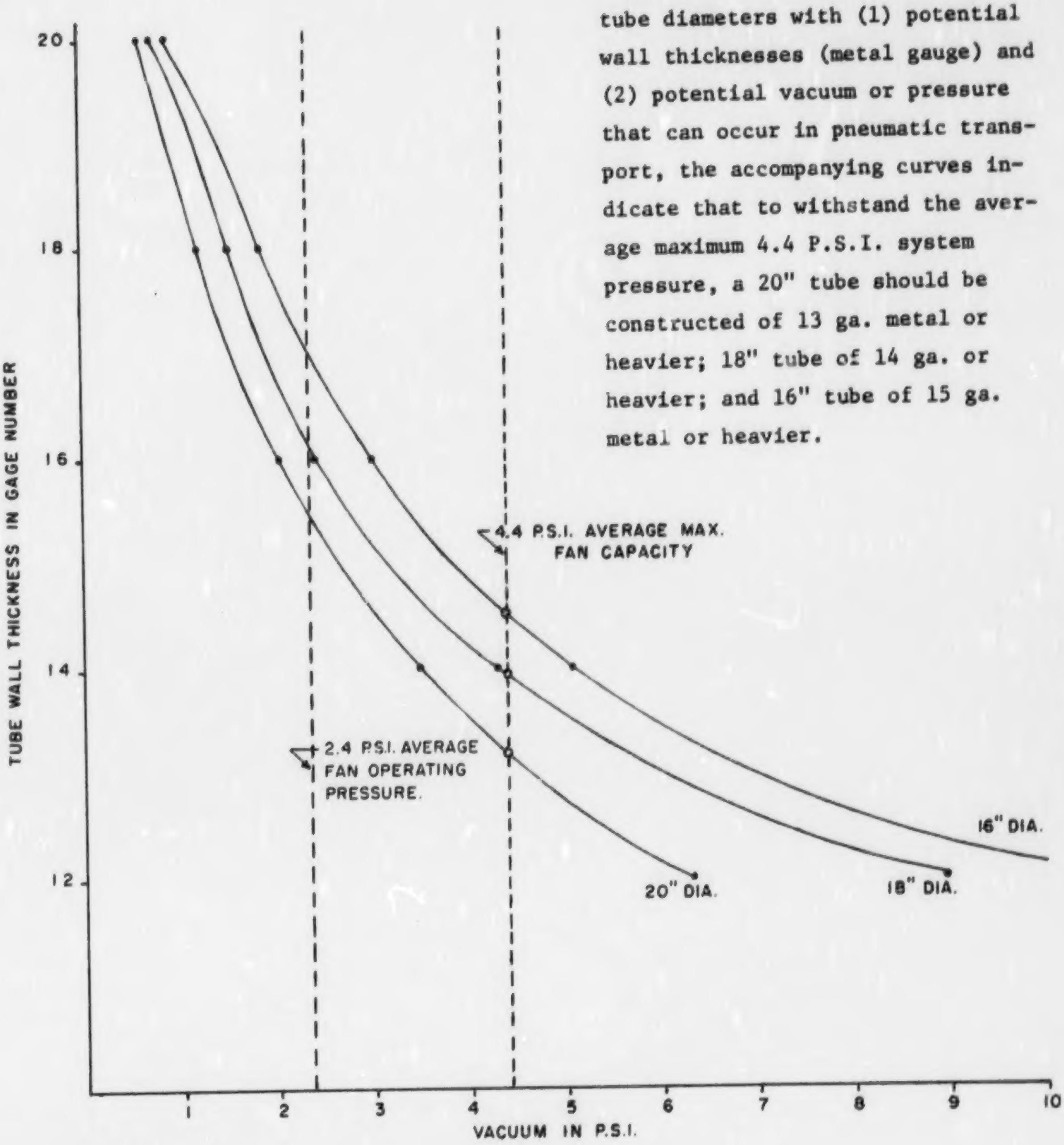


FIGURE 3.
ALLOWABLE VACUUM FOR VARIOUS DIAMETERS AND WALL THICKNESSES OF PNEUMATIC TUBES SUPPORTED EVERY 8'

consultants and, after installation, the entire system is tested against this by artifically plugging the inlet air. All elements must pass this test before the system is accepted. Secondly, relief valves are being placed at the end of the system immediately before the fan. When vacuum reaches a predetermined danger point, the valve opens to atmosphere to avoid both fan motor damage and collapsing of tubes. Thirdly, specifiers have begun calling for much heavier tube and fittings than 18 gauge steel and this entails quite different fabricating and coupling methods. The calculations given in curves in Fig. 3 show engineering requirements that must be met.

Mild steel can be lock-formed to manufacture a tube in 18 gauge thickness, and, with heavy equipment, even in 16 gauge thickness. Heavier tube walls than this are normally seamless welded.

The gravity-pneumatic systems use up to 1/4" wall thickness in seamless pipe or tube for pneumatically transporting waste, and with round cross section fittings in wall thicknesses up to 3/8 in. However, as the vertical chutes in the gravity-pneumatic systems do not have a vacuum pulled on them, they can be built of much lighter metal than the tube at the base that transports the waste under vacuum. Normally, the chutes are built to the same strength specifications found in other top-grade gravity waste chutes (14 or 16 gauge).

As the fittings (elbows, Y's, tees) appear to be the most subject to abrasion in waste movement, it is now common practice that they be specified at least one metal gauge heavier than the straight lengths of tube, and always in round cross section to provide smooth air flow.

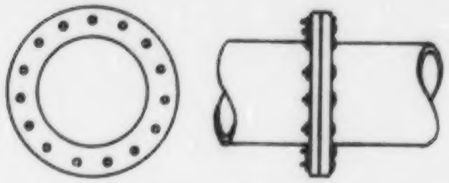
The heavier wall welded tube requires entirely different coupling methods. The original Swedish designs for heavy-wall tube called for butt welding each length to the next. This proved to be far too expensive. Further, weld flashes inside the tube were very difficult to grind smooth. Unless this was done, bag ripping could result.

It must always be borne in mind that the most successful pneumatic systems have the most even and smooth inside surfaces to provide excellent air flow without turbulence and complete absence of bag tearing. In this respect, they are no different from small pneumatic message tubes. This means that

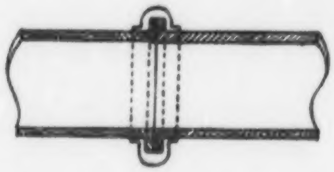
A rather wide range of methods is used to join together or couple the straight and curved tube sections. These include, for the lighter gauge tubes, formed flanges with bolt holes held together by as many as 15 bolts, with gaskets between to ensure air-tight seals; flanges that are covered on the exterior by a clamp ring to provide for rapid assembly and disassembly; and various support strapping devices.

For the heavier wall tubing and fittings, the thickness of the tube permits machining or chamfering the edges of the metal and welding the two sections together. In addition, external sleeves can be cemented or welded on to the tube to increase the rigidity of the joint. Ball and socket methods have also been used, combined with welding.

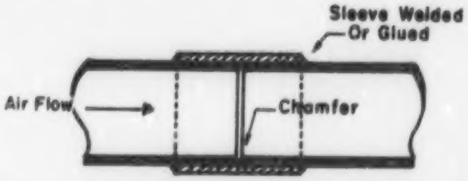
The smoothness and concentricity of the joins are absolutely essential to avoid bags ripping in transit. It is extremely important that inspectors be present during installation to see alignments are made properly.



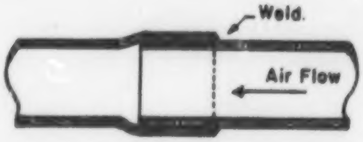
1: FLANGE AND BOLT COUPLING METHOD-FOR TUBING 16 GA. AND LIGHTER.



2: CLAMP COUPLING METHOD-FOR TUBING 16 GA. AND LIGHTER.



3: SLEEVE COUPLING METHOD-FOR HEAVY WALL TUBE.



4: BELL AND SOCKET COUPLING METHOD-FOR HEAVY WALL TUBE UP TO 1/4"

FIGURE 4. COUPLING METHODS USED IN PNEUMATIC TUBE SYSTEMS

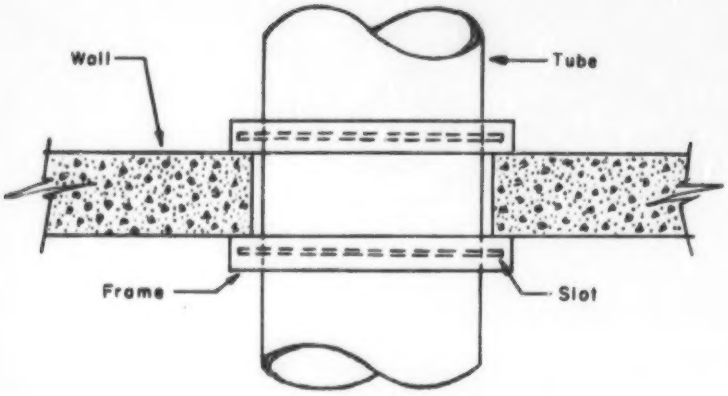
when two tubes, or a tube to a fitting, are joined, the alignment must be as perfect as possible. Slip joins that are externally welded, or bell and socket chamfered joins, provide this type of alignment in all seamless welded tubing that is 14 gauge and heavier in thickness.

Despite the fact that these are pneumatic systems with a powerful vacuum in force in the tube, the designers are extremely cautious when it comes to raising waste vertically. This is based on experience in the sort of items found loose in these waste systems (such as a 4-ft length of steel pipe). They prefer to rise vertically in slopes not exceeding 30°, with clean-out ports at the bottom of such risers for the removal of overweight solid objects that may be put in the system.

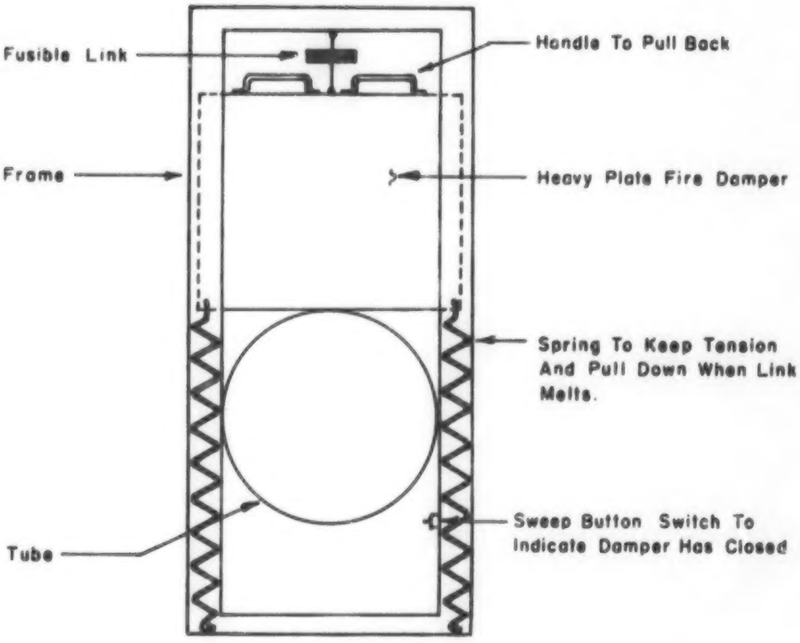
FIRE DAMPERS

One part of the tube system still presents a problem. Codes require fusible link fire dampers wherever the tube penetrates a fire wall. This means an actual gap exists in the smooth tube wall. At this point, a turbulence is always created in the air stream which instantaneously balloons out the transport bag or tends to hurl loose waste particles in the opening. It is essential that such dampers be well constructed, with no sharp corners in the interior surfaces, and that the fusible link and damper holding device in no way projects into the interior of the tube in a way that could rip a waste bag. An inspection of these devices reveals that much further thought should be devoted to their design and construction. Too often the latches have broken from vibration and closed the fire damper, causing serious plugging of the system.

The concern for spread of a fire is not from a fire starting within the pneumatic system, but rather one starting in a room and spreading through a fire wall. The fire could melt thin wall tubing and pass through the fire wall, melting further tubing on the other side and hence spreading to adjoining areas. If this is the logic, it would appear more desirable to place the fusible link on the exterior of the tube and a much heavier metal and a


Wall
Tube
Frame
Slot

PLAN


Fusible Link
Handle To Pull Back
Frame
Heavy Plate Fire Damper
Spring To Keep Tension And Pull Down When Link Melts.
Sweep Button Switch To Indicate Damper Has Closed
Tube

ELEVATION

FIGURE 5. FIRE DAMPER DESIGN

different guillotine door device than currently used. The drawing in Fig. 5 is a suggested approach that appears practical. It has the further advantage of permitting reopening and fastening the door from the tube exterior.

TUBE AND CHUTE HANGING METHODS

Another extremely inportant aspect of installing such tube systems is the method of hanging or fastening the assembled tubing and fittings to the building structure. For years, arguments existed on small message tube systems as to whether the lines should remain flexible and move as the carriers traveled through or whether they should be mounted rigidly.

On the large diameter (16 in. and up) pneumatic waste and laundry tube systems, there is no argument. With potential weights of over 18 lb in a single laundry bag, traveling at up to 4800 ft per minute, the consensus is that the tubing must be held rigidly to reduce noise level and prevent fatigue at all joins. Tube hangers must be of sufficient strength to prevent shearing from metal fatigue and well fastened into solid concrete in such a manner that they cannot vibrate loose; and installed as frequently as one every four feet of tube length.

Chutes and loading hoppers also must be mounted rigidly and supported at each floor level to the building structure to avoid fatigue from the "bounce" effect of a heavy load tumbling downward. This also applies to collectors and diverter valves.

SYSTEM COATINGS AND ABRASION

Three types of considerations are involved in coating the tubes and fittings used. First, there must be moisture protection for the tubing if it is buried below ground and subject to water attack. While stainless steel, rust-proof tubing has been used in these areas, it is limited to the lighter metals of down to 16 gauge and is quite expensive. A more common method is to wrap or coat mild steel tube for corrosion protection in accordance with AWWA specifications.

The second consideration concerns sound deadening of exposed pipe and fittings. Various materials such as fiber glass or magnesia are used to wrap the pipe after installation, in thicknesses up to 2 in. and densities up to 3 lb.

Thirdly, the interior surfaces of mild steel tubing are often coated with galvaneal or epoxy paint to ensure a rust proof lining, particularly with laundry tubes.

Abrasion of the tube has been discussed at considerable length by the designers of these solid waste systems, both in the United States and in Europe. A mixed bag of waste can easily contain as high as 25% glass which is subject to breakage, and total waste from a hospital can contain as high as 10% abrasive material--glass, metal, etc. In Sweden, abrasion tests on tube elbows, of a radius three times the tube diameter, measured tube wall erosion as high as 1/64 in. per year. To combat this, the latest designs request radii in bends of as much as five times the tube diameter (which cuts the erosion figure in half); with a minimum of three times. If the 1/64 in. or .0156 in. of erosion per year holds true, 20 gauge sheet steel is only .0368 in. thick, and hence could wear through in slightly over two years at the erosion point. Fourteen gauge at .078 in. would last five years, and 8 gauge would last 11 years.

Several light gauge systems carrying trash have been installed in the U.S. and do not appear to show wear this drastic. However, conservative engineering indicates that 14 gauge metal is preferred as a minimum for tube elbows and that, wherever the architectural considerations permit, radii be five times the diameter of the tube and never less than three times the diameter.

DIVERTER VALVES

Single tube systems that handle both solid waste and laundry must have diverter valves to direct either the waste or the laundry to the proper collector box at the end of the line. These have been a source of problems in this system design. If the operating relay hangs up, the valve may not swing into proper position. This also applies if the air cylinder operating the valve malfunctions. Further, the valve must swing shut completely to avoid line leakage and particles of trash getting into soiled laundry. The valve interior that shifts to divert the load must be designed and constructed so that loose paper or linen cannot jam it at the edge, or lodge on it and prevent it from closing tightly.

The latest designs in such valves appear to be much more efficient. Instead of a plate swinging over within the tube to direct the flow, an entire inner tube swings over, ensuring a complete continuation of the tube system. A recent test, in which the older style plate-type diverter was replaced by the tube type, showed a considerable increase in vacuum pull in the system, indicating the increased efficiency of the new style valve and lack of line leakage.

COLLECTOR BOXES

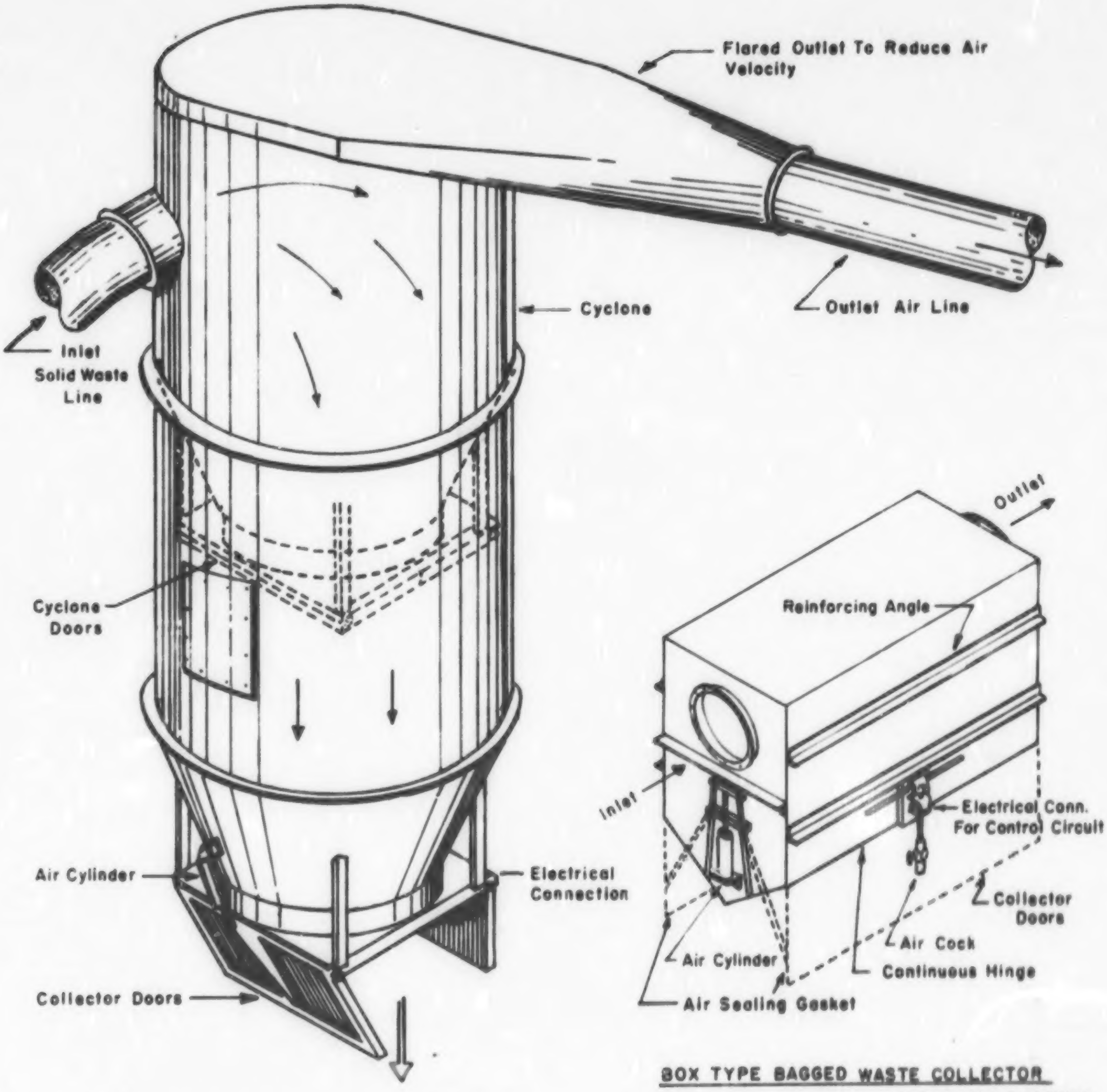
As described earlier, the bagged or loose solid waste and laundry is carried to a collector box, hopper or tank at the end of the transport tube line, and the air stream continues through a port in the box to the suction fan. The material being transported hits the interior of the box at full speed, usually entering into it at a speed of 80 ft per second or 4,800 ft per minute. This is approximately 55 miles per hour. When a bag of laundry weighs as much as 18 lb, or when a bag of waste contains heavy glass or metal, the shock to a square box is fairly substantial. Further, every attempt is made to keep the effluent air, exiting the box to the fan, as free as possible from lint, liquids and debris. Screens protect the outlet port for this purpose and they, in turn, must be protected from either being damaged by the blows from bags entering the box, or from flying debris clogging them.

At the bottom of the box are doors that open at the end of the transport cycle to let the solid waste and laundry drop by gravity into a container, compactor, cart, etc. below. The rubber gaskets on the doors, providing an air seal, are a major maintenance item. Examination of maintenance records has revealed that the hinges used on collector box doors were a weak point subject to frequent shearing. It would appear that heavier duty and continous hinges should be used.

The first collector boxes were not sophisticated in design and were originally used only for laundry. They were ruggedly constructed of heavy plate and normally accepted a single bag at a time. As solid waste systems became more common, it was seen that a collector box that worked well for laundry did not necessarily serve solid waste as well. One of the main problems in waste was bag breakage and glass breakage when hitting the collector. Secondly, there is a tremendous variation in weight between the various elements in the waste, ranging from light paper or plastic films to heavy metal, glass or wood. This makes the separation process difficult between the drop-out of the waste and the discharge of clean effluent air to the fan without clogging the debris screen with "fines," or lighter particles of paper and plastic in the waste.

As a result, the designers turned to principles used in industry and introduced either cyclone inertial separators, or widened discharge tubes in the collector boxes. With the cyclone separator design, the box has a cylindrical top and conical bottom. The cyclone designs used as waste collectors at the end of the pneumatic tube systems work slightly differently from standard industrial cyclones.

The waste enters at a tangent, whirls around the circumference at the top and works its way inward and down at a reduced velocity. The downward motion of the air drives the trash, including fines, to the bottom of the cylinder. Here it is received into a middle section by pneumatically operating doors. On a timed cycle it is dropped out of this by a second set of pneumatic doors into a compactor bin or other receiver below the collector. The effluent air leaves through a flared tube at the top of the cylinder with a much wider opening than that in which the air stream entered the collector. This has the effect of reducing the escape velocity in proportion to the


Flared Outlet To Reduce Air Velocity
Outlet Air Line
Cyclone
Inlet Solid Waste Line
Cyclone Doors
Air Cylinder
Electrical Connection
Collector Doors
Outlet
Reinforcing Angle
Inlet
Electrical Conn. For Control Circuit
Collector Doors
Air Cock
Air Cylinder
Continuous Hinge
Air Sealing Gasket

CYCLONE TYPE BAGGED OR LOOSE WASTE COLLECTOR FOR LARGE VOLUME OR MULTIPLE LOADING SYSTEMS

BOX TYPE BAGGED WASTE COLLECTOR FOR SMALL VOLUME, SINGLE BAG SYSTEMS

FIGURE 6. TYPICAL DESIGNS OF SOLID WASTE COLLECTOR BOXES

ratio of the two openings.

Other collectors employ a physical separation of the effluent air from the fines and light waste, that could be either carried through in the escape air to the fan, or could clog the exit screens. The most common principle is to greatly enlarge the exit opening in relation to the size of the entering air stream, reducing exit air velocity to allow the lighter waste to descend by gravity instead of continuing with the exit air.

Mathematically this can be illustrated as follows. Assuming the diameter of the inlet or transporting pipe to be 18 in., this is 1.77 square feet of area. It has been determined that a good air exit rate to avoid screen clogging is 4 ft per second. This is at 1/20th the rate at which the solid waste air stream enters the collector when it is traveling at 80 ft per second. Therefore, to achieve the reduced velocity, the air would have to escape through a flared tube in the side of the collector that is 20 times the cross section of the inlet pipe (1.77 square feet), or 35 square feet, which eventually would taper down to the regular tube size of 18 in. for return to the fan. To avoid most light particles being caught in the effluent air stream and clogging its protective screen, it is probable that the exit port would have to be twice this size, reducing air flow to 2 ft per second.

The present boxes and cyclone type collectors are a compromise in this direction. Drop-out of the trash by gravity is quite gentle and the amount of light material clogging the debris screens has been drastically reduced. Automatic compressed air blow-down systems are being added to keep the screens free of the remaining debris.

THE FAN ROOM

From a design and construction viewpoint, the fan room and all its equipment is one of the most critical aspects of the system. It is essential that the room be adequately ventilated and that the temperature not exceed 80 F during operation, in order to protect the electrical equipment installed in the area. Despite sound attenuation, the noise of the fans and the air exhaust is substantial and potentially dangerous to the human ear. The entire room should be constructed of dense enough walls, floor, and ceiling to prevent sound transmission. Doors must be large enough for equipment removal in case of replacement and should be sound gasketed.

Two types of fans are in general use: the enclosed, positive displacement, centrifugal, turbine type exhauster, operating at relatively close tolerances, and the much more open, loose tolerance, typical materials handling type or exhaust fan. Motors in ranges from 100 to 250 HP are used to drive these fans. Adequate transformers and feeder lines are essential to eliminate voltage drop with these large motors.

Regardless of the type fan, they are heavy and, when running at full speed under load, create a considerable vibration. It is standard practice to mount the fan and motor assembly on vibration isolator pads, inertia blocks, spring type isolation bases, etc. It is essential that there be sufficient size and mass to fulfill the purpose intended.

Maintenance of the fan and motor has some special features to it. In many installations, the fan bushing has been attached to the motor shaft by heat expanding the shaft for positive union. Cases are reported where it has been almost impossible to separate these at the site and, in order to perform motor maintenance, the entire motor-fan assembly has to be removed. For motor maintenance it is important that the room be designed to facilitate such removal.

FILTERS

While the positive displacement fans are more efficient than the more open materials handling fans, due to close tolerances the blades must be protected from waste particles being carried through them. It is good practice to place a 2 micron bag or roll filter ahead of the fan to protect the blades from such airborne contaminants. This has the further advantage of cleaning the exhaust air, before it reaches the fan, of most micro-organisms and thus protecting the environment from the fan exhaust. The filter must be exceedingly well constructed, capable of resisting the maximum vacuum created by the fan. Also, it adds considerably to the air resistance, even in its clean state (as much as 7 in. water), resulting in the fan having to be sized large enough to compensate for this.

With the more open tolerance exhauster fans, some manufacturers claim pre-filters are not required to protect the blades. This may be a risky claim. Where pre-filters are not installed, many maintenance men have discovered lint and waste materials adhering to the fan blades to the point where the fan, revolving at over 3,400 RPM, was thrown out of balance. In one hospital, the motor base mounting bolts sheared and the base of the housing cracked from the excessive vibration. It is strongly recommended that pre-filters be installed ahead of the fan to catch both fine particles and heavier debris that may be in the air stream. They must be easily removable for maintenance and strong enough to stand both the air pull and debris in the air. The same requirements of 2 micron filtration should exist for these more "open" fans as in the positive displacement fan. This filtration for environmental protection could be incorporated in the debris filter ahead of the fan or in a second, bacterial filter on the fan exhaust side.

SOUND ATTENUATORS

The large, heavy-duty exhauster fans and motors are obviously not noiseless when operating. An extremely large volume of air is being exhausted outside the fan room. A good rule in designing such systems is to ensure that a sound attenuator of adequate design and construction is installed after the fan so as to achieve a total noise level of less than 60 decibels on the "B" scale when measured at the exterior walls of the building housing the fan assembly. The higher the octave band, the lower the maximum decibel rating should be, in order to prevent annoyance to patients, staff, and visitors. The following gives the allowable maximum noise levels suggested for various octave bands.

OCTAVE BAND (cycles per second)	MAXIMUM LEVEL (decibels)
37-75	67
75-150	62
150-300	54
300-600	47
600-1200	41
1200-2400	35
2400-4800	29
4800-9600	27

RELIEF VALVES

An integral part of the fan assembly and tube system should be a relief valve placed in the tube before the fan. The purpose of this is to avoid either fan and motor damage; or tube collapse (if the lighter sheet metal tubing is being used) when for some reason the system plugs and creates a vacuum higher than the maximum operating design. Such a valve is normally connected by a tube to the outside air and when the maximum is reached it opens and the fan pulls this air. Alternatively, a switch can activate to shut down the exhauster fan in case of too much vacuum being pulled.

FEED AIR

It can be seen from the previous discussion that the air feeding the system, whether from roof dampers in a full vacuum system, or from basement level tubes in a gravity to vacuum system, should be dry and clean. In extreme northern climates during winter this has occasionally created problems when the inlet air drawn through roof dampers is as cold as -30 F. and is entering a building with temperatures of 70 F. Moisture and condensation may become a problem with the rapid rise in temperature and in severe cases may require pre-heating of the air.

COMPRESSED AIR SYSTEM

Most of the moving parts in the system are activated by rapidly moving compressed air cylinders. This applies to roof and fan dampers, inner chute doors, collector box doors, diverter valves, and slide valves. It is essential that the compressed air be filtered and lubricated and that all lines and valves be made of rust-proof material. The usual pressure in this system is 125 p.s.i.

This usually requires a separate air compressor used exclusively for the pneumatic tube system. In many installations, it has been seen that the systems manufacturer under-calculated the total CFM of air required and the size of the compressor, with the result that the action of air valves was slower than necessary. Other design factors that have been discovered is that all air cylinders should have individual oilers. Low points in the compressed air lines should have bleed-offs to drain out any collected moisture. In northern climates with protracted periods of below zero temperatures, air dryers should be installed in the line, effective up to -60 F, to prevent the air freezing exposed cylinders such as in roof dampers.

ROOF AIR INLETS AND DAMPERS

On the full vacuum system, the inlet air is obtained from double blade gooseneck shaped vents installed at the top of the vertical chutes through the roof and projecting above the roof level approximately 48 in. The dampers in this are activated by compressed air for opening and closing.

In the gravity-pneumatic systems, the vents appear similar in design and have a weather-tight vent relief terminal cap. They also contain a barometric damper to maintain 1/4" negative pressure in the vent and a fusible link in the top door in case of chute fire.

SPRINKLER SYSTEMS

From actual observation of tests with gasoline-soaked rags that were ignited and thrown into a full vacuum system, it appears highly doubtful that the tube system will support open combustion. However, a small smoldering fire could possibly continue inside a bag of trash. For this to lead to a fire in the system, there would have to be a plug or a system shut-down, as on the average the burning material would be dropping out of the waste collector in 40 seconds, much less remain in the vertical chute. With a gravity to pneumatic system, the situation is different and there can be storage on top of the slide valves at the chute bottom for a prolonged time period.

Half inch sprinkler head stations are usually installed in both types of systems at the station below the roof line in the vertical chute and at every other floor, or every floor, descending to the lowest. In addition, occasionally sprinkler heads are installed in the trash collector boxes. Sprinklers are normally fusible link activated.

LOADING STATIONS

The loading stations are normally faced with a stainless steel panel from floor to ceiling. There is usually a maintenance door as well as the chute loading door. These must be U.L. Class "B" labeled, rated at 1-1/2 hours at 250 F. Station doors are either stainless steel or aluminized steel and are normally side-hinged and self-closing. Bottom-hinged foot pedal operated doors are used on the waste chutes of gravity to vacuum systems. Regardless of the hinge system, bottom hinged doors can present problems in that personnel may rest a heavy bag on an opened door and spring it. The majority of these chute doors have a 36 in. height from the floor. Some of the gravity-pneumatic chute doors are as low as 24 in. from the floor to the loading sill. The buck material is usually stainless steel to ensure cleaning ease of the door frames.

Maintenance door fasteners, in most systems, are merely a series of screws, attaching a maintenance panel to the buck. It is felt that for preventive maintenance this is a poor method and should be replaced with a hinged panel and a lock and key to open it, or some other quick opening, tamper-proof method.

Signal lights are normally positioned in the wall panel, always a red "In Use" light, to warn prospective users that, either the door is locked, or the inner hopper door is open and unavailable. Alarm lights or buzzers are rarely placed at the chute doors. A central maintenance location is preferred. However, there should be an "Out of Order" flashing light at each station to warn the operators of a shut down, whether due to maintenance work or a breakdown.

Most important, prominently displayed over each loading door is an identification sign such as "Trash" or "Solid Waste"; "Linen" or "Soiled Laundry." It is essential that these signs be distinctive and boldly lettered. In come hospitals, instruction signs or plates are placed over or adjacent to the loading doors.

CLEAN OUT PORTS

We would like to report that plugs never occur in pneumatic transport systems, but unfortunately this is not the case. Virtually all such tubes get plugged with linen and trash from time to time, for a variety of reasons, ranging from operator carelessness in using the system, to mechanical-electrical malfunctions. In single bag systems, plugging is usually caused by operators attempting to override the system and force multiple bags through simultaneously. There are two types of plugs experienced. The first is self-clearing, when the removal of a bag or two and the applying of full fan vacuum will allow the plug to free itself. The second is more serious: the entire plugged load must be removed by hand ("fished") from a clean-out port, or a chute station, or a collector at the end of the line. With 500 feet of horizontal tubing, this could take time.

This explains the necessity for clean-out ports in horizontal tubing, or where horizontal runs transfer to upward risers. To have to remove sections of tube to clear a plug is an extremely expensive job for the maintenance department.

When installing clean-out ports, it is essential that they be constructed in such a way as to not weaken the tube wall; that the interior tube surface be completely smooth and free of projections where it joins the clean-out port; and that each port be large enough to permit the removal of a full bag of solid waste or laundry.

CONTROL SYSTEMS

The heart of the electrical operation of all pneumatic waste and laundry transport systems is the central control panel. This monitors all loading stations and supplies the logic, through a succession of relays and breakers, that sequences the opening and closing of all pneumatic cylinders and valves, which in turn control the routing of air (and hence material) through the system. It cycles the stations and provides the memory circuits for determining the order of priority for such cycling (either pre-programmed or first come-first served). It reads the pressures and vacuums in the entire system and protects it from damage due to excessive build-up by supplying "fail safe" shut down actions.

A master switch controls power to the control panel and through it the entire system. In addition, there are usually separate switches to turn the exhauster fan on and off and to run it manually or in automatic sequence. There is usually a high pressure safety switch which activates automatically by a sensor when vacuum exceeds allowable limits. This throws open the relief valve and/or shuts down the exhauster fan. Before the system can be returned to normal operation, this switch has to be reset after the cause of excessive pressure has been corrected.

Various types of memory systems have been designed into such a control panel and each year the electric designers have made these more sophisticated, up to the point where mini-computers are now being considered. As the systems get more complicated by building them with increased number of stations, the need for speed and accuracy in the circuitry increases. The bulk of the full vacuum systems have memory systems constructed with stepping relays to activate the station unloading. Originally, these were quite simple. Whoever pressed the first station button sent his signal to the first activating relay. The second button pushed sent its signal to the next relay, where it was held until the first sequence was completely cleared; and so on through a potential of 50 or more stations. Activation had to take place by throwing or pushing switches at the station doors.

As we have seen earlier, with the gravity-pneumatic systems this is not the case. Adjustable time clocks run the system by determining when the valves should open and they open and discharge into the air stream in a predetermined sequence, whether they contain a waste load or not.

As the full vacuum systems have been installed more recently, they have leaned in this direction and cycled in a predetermined fashion. However, only the loaded stations operate. They usually cycle one chute at a time in sequence, such as all the loaded laundry stations for the entire system, then all the loaded waste stations. One problem that has been noticed is that if the opening of the station inner doors start at the bottom and work up to the top in a given chute, the inner door must close on time and completely to prevent a bag from the one above it catching on it and creating a jam. Sequencing from the top down has proven desirable.

SUPERVISORY PANELS AND ALARM SYSTEMS

From rather simple and crude beginnings, during the past five years the supervisory panels have improved considerably. They now show the complete schematic of the system and the exact status, at a point in time, of all major elements, by means of small lights superimposed on the schematic plan.

One of the hospitals studied constructed its own panel, complete to the point where the approximate location of a plug in the system can be identified instantaneously.

In the complex supervisory panels, alarms are included, either in the form of flashing lights or buzzers, or both. The panels monitor items such as incomplete cycles, loading hopper doors not closed, collector box doors not closed, diverter valves open, roof dampers open, low or high pressures in the air flow, high temperatures in fan exhaust, slide or butterfly valves not opening or closing, dust filters loading up and exerting too much air resistance, etc.

The monitoring of supervisory panels and the resetting of switches, relays, timers, etc. in the control panel is the function of the Maintenance and Engineering Department. It is therefore essential that these elements of the system be installed where they can be reached easily by maintenance personnel or are under their constant and convenient surveillance. Too often architects and mechanical engineers designing the structure are inclined to "bury" such panels.

CYCLING TIMES IN PNEUMATIC SYSTEMS

The time that it takes a pneumatic system to perform a complete cycle depends on several factors: the design of the system, whether full vacuum or gravity to vacuum; whether it is a single or multiple bag loading design; the speed of travel of the material as determined by a combination of the suction force and the weight being transported; the length of total run from the collectors to the station farthest away from each collector; and the pauses or delays built into the control panel by the manufacturer for sequencing the various components in order to be sure that valves, doors and dampers have time to open and close without jamming the material being transported.

It should be realized that cycling is on a "constant" time, not a "variable," in the design of virtually all single bag full vacuum and all gravity to vacuum systems. What this means is that the time is fixed by the manufacturer, regardless of the length of run. If a bag can be transported in 10 seconds from the station nearest the collector to the end of the line, and it takes 50 seconds to transport a bag from the station farthest away from the collector, then the system is timed for all cycles at 50 seconds in order to achieve simplicity in the control system. With a key-lock, multiple bag system, overriding the normal time cycle of a single bag procedure, the operator has control over the length of the cycle, as he manipulates the station door switch.

In a full vacuum system, timing of the length of run starts when the bag drops out of the loading hopper into the vertical chute. With full vacuum, and in typical hospital height buildings, the bags do not descend the chute that much faster than in a straight gravity condition. Assuming a ten-story building with basement loading stations and with floor-to-floor heights averaging 13.5 feet, the total vertical drop might be 141 feet. In a gravity drop, a bag would take at least 2.5 seconds to cover this distance, assuming it could fall freely. Under an air pull that gives a travel speed of 80 feet per second, it would take 1.75 seconds.

Horizontal speed at a theoretical 80 feet per second would be 3 seconds for 240 feet, up to 12 seconds for 960 feet. The 80 feet per second is rarely maintained over the full run due to line losses, resistances, and slippages, so it is normal to add 25 percent to these times.

The balance of the time in the cycle is used up in activating the various components. These segments of time must be added to the travel time in order to arrive at the total cycle time. In the average full vacuum system, they are as follows:

	Seconds
Opening of air inlet damper	1
Opening of fan damper	1
Allowing air to achieve transport speed	2
Opening of inner hopper door and bag dropping	2
Shifting of diverter valve	1
Closing of inner hopper door	1
Closing of all dampers in sequence after allowing for travel time	3
Opening of collector doors to allow bag to fall out	2
Closing of collector doors to permit recycling	2
Total sequencing time	15

Hence, it can be seen that the sequencing of the system components can require as long as, or longer than, the travel time of the material. Timing of most full vacuum system substantiates this. An "average" total cycle takes approximately 30 seconds.

FINAL REDUCTION AND OFF-SITE REMOVAL

The care and precision of in-house transport of solid waste directly affects the health and safety of the staff, patients, and visitors in a hospital and equally affects the operating budget of the institution. The most serious effect on the environment and on the health of the community starts at the "end of the line," after the loose or bagged waste has been transported from the floors to some central location, such as the loading dock of the hospital, and must be removed off-site, with or without further treatment.

Management of hospital solid waste must be viewed as a total problem that consists of a series of steps in a complicated system. It starts with the disposing of a waste product in a trash basket or container in a patient room or support area, and is not solved until the residue waste (loose, compacted, ground, dumped to sewer, or incinerated) is safety treated in some location remote from the hospital, such as landfill or sewage treatment plant. All hospitals are subject to various external constraints, designed to interface with satisfactory in-house final treatment and reduction methods; and these must be compatible with safe off-site removal that ensures satisfactory public health and environmental conditions. A subsidiary consideration is that these final treatment and removal procedures also must be economically feasible: operating costs must be kept to a minimum.

As can be seen from the chapter that analyzes the make-up of hospital waste, 40 percent is potentially "hazardous." It consists of fomites capable of transmitting pathogenic organisms; pathological specimens; material from known communicable disease cases; disposables that are hazardous in nature from a secondary use viewpoint (plastic items, syringes, needles, and sharps); potentially infectious material due to contact with wounds, burns, or used in treatment of patients' surgical incisions; potentially infectious clinical and research laboratory wastes; human or animal fluids, secretions, tissues, and feces, and the disposable containers that hold these; toxic, flammable, corrosive, explosive, and radioactive substances that have detrimental effects on people, equipment, and property; and the solid waste that in the process of assembly and removal may either become contaminated by such known infectious and hazardous wastes and hence become infectious or hazardous itself; or is originally infectious or hazardous to a degree not clearly established.

The in-house final collection and treatment systems must consist of adequately designed and installed equipment and carefully managed operational practices, that completely avoid transmission and contamination problems among the hospital personnel. These systems must also ensure that the waste is satisfactorily treated, reduced, packaged, and containerized so that it can be moved to the off-site point of final disposition, safely and completely.

With waste loads skyrocketing and exceeding 11 pounds per patient day in many urban hospitals, the sheer volume to be managed, and the time and expense to manage it, is too often encouraging "short cuts." The cry of "get it away from patient, staff, and visitor areas and down to the dock and away from the hospital" is heard daily. In the process, safety measures can be ignored. The hospital staff, the community health, and the environment can all suffer accordingly.

Not only is hospital waste environmentally hazardous in varying degrees, it is proving more expensive to handle as each year passes. As can be seen from the chapter on the economics of hospital solid waste management, the expense is mounting at every step in the process, from original pick-up, through in-house transportation, through final collection, reduction, and treatment, to off-site removal.

VOLUME REDUCTION

When a bag of solid waste drops out of a collector at the end of a pneumatic tube line, or is dumped into a hauler's trash truck by hand, it is immediately apparent that in the total volume there is about 20 percent material and 80 percent air; that mechanical compression or compaction could give up to a 5 to 1, or 80 percent reduction in volume by simply squeezing out all the air and leaving the material. As off-site hauling contracts are based directly and indirectly on the volume of waste being hauled, as well as the weight, compaction or other volume reduction techniques reduce hauling costs.

A second examination of the original waste reveals that it is in all sorts of shapes and sizes, from flimsy paper and plastic sheets, through heavy cardboard and crating material, to strong containers made out of glass and sheet metal. And all of it is capable of being reduced to fairly uniform particle size by feeding it through the proper type of attrition mill or "hogg." It is discovered that, if it is decided to transport the ground waste to another area on-site, now that it is in a more or less uniform size particle, it lends itself to various materials handling techniques that would not accept the unground material. It can be handled and transported pneumatically in sealed, small diameter tubes; or mechanically in screw conveyors that are completely encased to avoid atmospheric contamination by the moving waste. If the ground waste is compacted at some point, it is discovered that a further volume reduction can be obtained, against compacting the unground waste.

A third examination of the total hospital waste delivered to the final in-house collection point reveals that 92 percent of the bulk is combustible under proper conditions, and after combustion the ash residue is quite small.

CLEANLINESS IN THE CENTRAL WASTE COLLECTION ROOM

From an examination of the solid waste central collection points in dozens of hospitals, it can be stated categorically that such an area can be as free of litter, as free of odor, as free of cross-contamination as is the lobby of the building. In fact, the environmental standards between the two areas in a hospital--public lobby and central waste collection area--could be the same, with proper foresight. To achieve this at the end of the line, design standards for equipment and the placement and interfacing of mechanical items are extremely important. Equally important are the rules for loading the equipment, and the managerial supervision over the people doing the loading in those instances where it is hand fed.

Cleanliness, lack of spillage, and freedom from odor can be achieved through sensible, well thought-out, and designed mechanization; and they can be achieved through rigid control over the actions of all personnel entering the area and hand loading solid waste into collection and/or reduction devices. Both tight mechanical control and human control are essential.

Design and construction of solid waste collection and reduction rooms absolutely must follow certain rules if environmental problems are to be avoided. The most important rule is that once waste reaches this point it should no longer be exposed to atmosphere, except in the case of a mechanical breakdown enforcing a divergence from the standard system. At all times, it should be in tightly covered bins, containers, conveyors, or machinery so that it does not spread throughout the room or the surrounding area. Most institutions have not paid enough attention to these points. In the hot summer months, odors from decomposing wastes are noticeable; loose waste spillages or "float" and liquid spillages can be seen.

COMPACTORS

Stationary compactors for the end of the line are designed to reduce the volume of waste that must be hauled off-site and thus reduce hauling costs. With the proper container or sealed mobile bin doing the hauling, the result is an environmentally safer trip, hopefully with no spillages or leaks along the way. A final advantage is that in the process of compaction much of the waste is destroyed, or at least so mixed with other waste that it is difficult to salvage it for secondary use, and thus create health hazards.

By 1972, over 20 manufacturers were merchandising over 150 different models of stationary compactors that can be installed in the central waste collection terminals of hospitals. The rate of compaction varies from 2 to 1 to 5 to 1 depending on the design, the size of the compaction bin, and the strength of the unit. The designs differ considerably, ranging from units with a high receiving volume and quick action that give only a modest amount of compaction, to units with extremely high compaction rates but much slower cycling time.

Sizing of the compactor depends on two direct considerations: the total quantity (cube) of waste being generated and the frequency on which it is desired to haul the compacted material off-site. The indirect consideration is the architectural space in which the compactor and hauling bin must be installed. In virtually all hospital installations the compactor is stationary. It is close-coupled to a closed steel container. The compactor contains a ram or similar device that forces the waste into the container, reducing the bulk as it compresses the waste. When the container is full with compacted waste, it is connected to a truck or tractor and hauled away.

Compactor containers used in hospitals are fairly large, on an average ranging from 20 to 40 cubic yards in size. They are also not the easiest mobile bins to maneuver. As hauling contractors also charge for the time required to pick up and drop off these vehicles, the location and ease of access is important.

In sizing a compactor and mating hauling container, it is obviously essential to know the cube of waste being generated each day and to determine the practical reduction given by compaction. Hauling contractors charge on a trip basis; the fewer the trips, the less the cost to the hospital. Hospitals thus attempt to use the largest compactor and container for the waste generated weekly, and balance this against the storage problems the waste can create. One limit to size of vehicle is the parking space available. Another limit is the amount of odor and possible environmental contamination the stored waste can create. Out of all these considerations, the hospital will size its compactor and container, for hauling weekly, or twice or three times a week.

The National Solid Wastes Management Association, Washington, D.C., gives a rating to over 135 different models of compactors on a set of 13 key parameters. The base size rating defines the charging capacity of the compactor, measuring the theoretical volume moved by the ram in a single stroke. The clear top opening, length by width, indicates the largest objects that will fall freely from top to bottom of the charging chamber. The ram stroke is the maximum linear displacement or forward stroke of the ram. The penetration of the ram into the waste container provides the uniformity of compaction and it clears the discharge opening of the container prior to decoupling from the compactor.

The speed at which the compactor moves materials into the hauling container is the "cycle time," measured in seconds. The theoretical upper limit of compactor output based on 100 percent utilization is the "machine volume displacement per hour," measured in cubic yards per hour. Compaction capability is measured in terms of pounds force per square inch on the ram face at stated actuator forces, such as hydraulic pressure.

Another important measurement is the discharge opening which defines the minimum dimensions for the opening of the mating container.

When a compactor is interfaced with a pneumatic tube waste transport system, an efficient and environmentally acceptable design can be achieved.

At the bottom of the pneumatic tube collection hopper there must be sufficient head height, along with length and width to allow the bagged or loose waste to drop out into the compactor receiving chamber without bridging. Waste arriving in the final collection room varies tremendously in density once it escapes from a bagged condition. The major problem is "float--fine particles and light weight pieces of plastic and paper, all of which may have become contaminated by contact with other waste. A second problem is liquids in the waste that can spill out of the transport path. The connection between the pneumatic system collector box and the compactor receiver chamber must be dust and liquid tight, so that when waste drops out of the collector none can escape. Further, the connection between this receiver chamber of the compactor and the hauling bin must be equally tight so that no waste escapes during the stroking of the ram. There is simply no reason why waste should be spilled, or float, in such mechanized systems. If it does, it is the result of poor engineering or poor construction.

The space alloted for installing a compactor should allow for properly servicing the equipment. When installed indoors or in a protected area, proper cleaning facilities should be provided such as hose and steam cleaner outlets, gutters, and floor drains. Also, fire protection devices such as sprinkler systems, extinguishers, or injection nozzles for chute fed units should be provided.

DRY GRINDERS, MILLS, AND HOGGS

The latest development in solid waste handling and reduction at the hospital central collection point is to lead directly from the chute collector box into an attrition mill or dry grinder, capable of reducing *all* waste into a standard particle size. This device must be selected to meet the requirements of handling a tremendous variety of material equally well: paper, cardboard, sheet metal and cans, glass bottles, wood products ranging from pencil size to heavy crating, plastic film and injection- or vacuum-molded plastic shapes, metal wire, rubber, textiles, animal and vegetable products. The minimum capacity should be 6,000 pounds an hour regardless of hospital size.

The oversizing of the grinder is to ensure that it is powerful enough to reduce any waste item being fed into it. All waste should be reduced to a particle size of from 3/4 in. to 2 in. diameter for ease of handling and mixing after reduction.

As in the case of the compactor loading compartment, the pneumatic chute collection box should load into the receiving chamber of the grinder, or mill, by a dust and water tight, heavy, steel plate transition section, designed in a way that there is no possibility of bridging. There should be a flexible connection at this point to positively prevent any transfer of vibration from the mill to the collector box, as well as the building structure.

The throat openings of such mills are sized to the capacity of the grinding or milling "teeth" or hammers to prevent overloading. The opening of a 3 ton per hour unit is approximately 3.9 square feet, which is comparable to the area of a 20 in. diameter tube or chute.

After grinding and reduction, the waste is normally transferred to a holding and mixing tank. This can be done mechanically in a completely enclosed screw conveyor, or it can be transferred by a materials handling fan pneumatically in an 8 in. to 12 in. diameter tube, and dropped into the holding tank through a cyclone that removes the excess air. This method also must involve a completely enclosed system from the attrition mill to the holding tank. When transferring ground waste pneumatically, the effluent air from the cyclone should pass through a 2 micron bag or roll filter to prevent contamination of the air outside the area.

The final step in the reduction is to compact the waste from the holding or surge tank; or to incinerate it. The holding tank must be of a design and construction that prevents bridging and, as stated, be completely enclosed. Normally, to provide a safety factor as well as a good mix of the waste particles, the holding tank should be large enough to hold a 48 hour supply of the hospital total waste. It can be sophisticated, with level sensors to provide maximum and minimum cut-offs in volume.

Whether incineration or compaction is the final step, the holding tank should have a "live bottom" of slowly moving screws. This has the advantage of mixing the waste into a fairly even mass. It ensures a homogeneous mixture of materials. It is also the most efficient method for moving the waste out of the holding tank and by completely enclosed screw conveyor into a compactor or an automatically fed incinerator.

INCINERATION

The ultimate disposal of hospital solid waste has an environmental affect on the air, the water, or the land--discharge of gases and solids from incinerators into the atmosphere, discharge of garbage grinders into sewers, discharge of solids into land fills. In recent years, the use of incinerators in hospitals, because of discharge of pollutant matter into the air, has been unpopular as the pollution regulations have become more stringent. To combat this, incinerator designs have greatly improved, from the single-chamber, smoke-belching, "black boxes" of the 1930's, to the multi-chamber units of the 1970's; with auxiliary burners, controlled overfire and underfire air, automatic feeding devices, and flue gas scrubbers. However, certain communities, who have studied the make-up of solid wastes in hospitals, with their heavy load of plastics, are worried as to whether the present advanced state of technology in incinerator design can yet meet the emission requirements, day after day.

It is generally agreed that a properly designed and operated multiple-chamber hospital incinerator with 700 F to 1,000 F in the primary and up to 2,000 F in the secondary, and with proper retention rates and complete combustion, will sterilize the most infectious and heat resistant organisms found in the waste. Emission of bacteria, viruses, or spores into the atmosphere will not be a problem. However, burning must be complete.

Entrained particulates and some gaseous elements are the major air pollutants emitted from the burning of solid wastes in incinerators.

The principal gaseous emissions from incineration are carbon dioxide, nitrogen, oxygen, and water vapor, none of which can be classified as air pollutants. However, trace gases in the emissions can cause some air pollution due to their odor; their effect on plants, animals, and property; or their interaction with components in the outside air to form undesirable secondary components. Chemical substances in this category are sulfur oxides, nitrogen oxides, carbon monoxide, hydrogen chloride, aldehydes, organic acids, ammonia, and hydrocarbons. Criteria exist in certain critical areas on nitrogen oxides and total hydrocarbons, and most areas place limits on permissible sulfur oxide emission. Except for the odor-causing elements, the remaining trace gaseous emissions are not of particular concern in air pollution control.

The particulates, or solids, suspended or entrained in the gas being emitted are of more serious concern as air polluters. Specific, quantitative emission limits of gas-suspended particulates have been written into all air pollution codes. The codes may be expressed in various ways, such as:
(1) total *weight* of suspended particulate per unit *volume of exhaust gases*;
(2) total *weight* of suspended particulate per unit *weight of exhaust gases;*
(3) total *weight* of suspended particulate emitted per unit *weight of solid waste charged.*

To obtain a standard of reference of the condition of the gas, and thus to prevent an incinerator operator from avoiding compliance with emission codes by diluting emitted gases with air or water vapor, almost all codes require correction of the emission limits to a specific reference condition. The most commonly used units for emission values are (1) pounds of suspended solids per thousand pounds of dry flue gas, corrected to 50 percent excess air, and (2) grains of suspended solids per standard cubic foot (29.92 in. Hg and 70 F) of dry flue gas, corrected to 12 percent carbon dioxide. These conditions are approximately equivalent for municipal waste incineration.

By 1966, the consensus of opinion was that emission limits should not exceed 0.2 grain of particulate matter per standard cubic foot of dry flue gas corrected to 12 percent CO_2 in incinerators burning 200 pounds or more of waste per hour (the usual size found in hospitals); and not to exceed 0.3 grain in incinerators burning less than 200 pounds per hour. The members of the Incinerator Institute of America adopted these standards in 1968 and guaranteed to meet them.

Many municipal and state codes also have established restrictions on the opacity of the emissions. These are based on the Ringelman chart. A visual observation is made of the stack "plume" with the Ringelman chart or scale. This is a series of reference grids of black lines on white that, when properly positioned, appear as shades of gray to the observer. The use of the chart takes a trained technician to achieve consistent visual evaluations. Most codes require that: (1) the normal, continuous plume quality not exceed Ringelman No. 1; (2) for short periods, not exceeding 3 to 5 minutes, plume quality not exceed Ringelman No. 2.

To control emissions of suspended particulate matter in the effluent gases from an incinerator is not a simple matter. The first requirement is an efficient design of the incinerator itself to ensure that the waste is properly and completely burned in the primary chamber and that the gases are retained for a sufficient time period in a secondary chamber to burn the particulate matter still further. Many designs add mechanical devices to remove the particulates from the gas. The first of these were settling chambers. Starting around 1957, some units incorporated wetted baffle-spray systems with screens and baffles and water sprays. Other units incorporated cyclone separators. More efficient than the wet baffle and spray systems have been the wet scrubbers. In these, the entrained particulates must combine with the water itself rather than water flushed impaction surfaces. The particulates collide with water droplets to effect capture. The particles and the water droplets then form larger droplets that are collected. The efficiency of well-designed scrubbers is as high as 94 to 96 percent. A problem is that certain chemicals in the gas, when in contact with water, form corrosive substances, such as hydrogen chloride forming hydrochloric acid.

Other methods used to trap particulates are electrostatic precipitators and fabric filters of fiberglas, asbestos, or high-temperature synthetics.

W.P.A. has suggested that there should be no more than 0.08 grain of particulate matter per standard cubic foot of dry flue gases, corrected to 12 percent CO_2 (against the present standard of 0.2 grain per cubic foot). This is the equivalent of 1.6 pounds of particulates per ton of solid waste burned and means that particulate removal would have to be 95 to 98 percent efficient.

Estimating, in 1973, the solid waste generated at 10.2 pounds average for 1,200,000 patients per day, this is 6,165 tons of hospital waste per day for the United States. If all this waste were incinerated, it would amount to 4.9 tons of particulate emission into the atmosphere per day for the whole country, if the 0.08 grain standard were consistently met. As all solid waste burning of every type, from all sources, in the United States generates less than 4 percent of the estimated particulate matter discharged into the atmosphere, this 4.9 tons appears a rather infinitesimal amount.

In 1968, the Incinerator Institute of America published their Incinerator Standards. Stating that the "basis for satisfactory incinerator operation is the proper analysis of the waste to be destroyed, and the selection of the best equipment to destroy that particular waste," they classified mixtures of waste most commonly encountered as "Types 0 through 6." They then classified incinerators by capacity and type of waste they are capable of burning as "Class I through VII."

Many hospitals have stated that reading these incinerator standards and waste classifications does not seem to solve their problems. Most hospitals require incinerators with burning rates from 500 to 1,500 pounds per hour and capable of handling solid wastes as are typically generated by hospitals. What they ask of the manufacturers and consultants is specific data on the incinerator that should be installed to achieve desirable emission rates. The Incinerator Standards leave this matter literally up in the air as far as typical high volume plastic and paper content is concerned.

The question to be answered is whether hospital-operated incinerators can consistently meet an emission rate as low as 0.08 grains per cubic foot. The experience in Los Angeles with locally constructed incinerators burning hospital wastes with large plastic content has shown that to consistently maintain 0.3 grains per cubic foot was difficult with the loading and mixing methods they used, despite the fact that the Incincerator Institute guarantees to meet 0.2 grains for this type unit.

With automatic feeding of the incinerator on what amounts to a "B.T.U. demand" basis, burning can be controlled very accurately. With a waste that is well mixed, both as to particle size and as to content (paper, plastic, wood, textiles, etc.) a fairly even-burning fuel is injected into the primary chamber, load after load. This solves most of the stack emission problems that have occurred in the past and assists in meeting all present air pollution standards during burning. This assumes that the incinerator is of a modern design with proper temperatures and holding times in both the primary and secondary chambers. Several recent tests, on a continuing basis, reveal that a system of automatic grinding, mixing, holding, and feeding of typical hospital solid waste into a properly designed incinerator can consistently achieve emissions lower than 0.1 grains of particulate matter per cubic foot of gas. A few such systems, as the forerunners of several more, are going on line in 1973 and will provide the nation with test data on a continuing basis. They are tied into pneumatic tube delivery systems and are completely automated.

There is a definite trade-off of environmental effects, between the emissions of properly managed incineration, and the effects of hauling and dumping the raw hospital wastes in landfills. In the balance there appears to be far less environmental hazard in the route of properly managed incineration.

Incineration obviously has definite advantages in handling hospital wastes. With incineration, the original waste is sterilized completely, both with regard to the solids and to the gases. The material hauled off-site does not create known problems to either the environment or to the public health of the community. It is reduced in volume by 90 percent or more, resulting in low hauling costs of the ashes. Further, after such reduction only a small portion of the original total is placed in land fill, thus extending the useful life of these valuable sites that are becoming increasingly scarce in our urban areas.

With properly designed and controlled plants the volume reduction in municipal incineration is estimated to be from 80 to 90 percent. It is also estimated that 98 to 99 percent, by weight, of the combustible materials can be converted to carbon dioxide and water vapor. Total weight reduction of the waste (with the non-combustible solids, such as glass included) is commonly 75 to 80 percent when it is converted to a dry residue with all the water content evaporated. Compaction of this residue results in further volume reduction, so that the compacted remains may be as low as 4 to 10 percent of the original volume.

The reduction in weight and volume of hospital waste by incineration is even more impressive than with municipal waste, due to the far higher percentage of completely combustible paper and plastic products in the hospital output. The make-up of the volume or cube of hospital waste is approximately the following:

Paper and cardboard	60.0%
Plastics	21.0%
Rubber and gums, natural and synthetic	0.5%
Textiles, cotton and synthetic	7.5%
Animal products	0.5%
Wood products	1.5%
Food products	1.0%
Glass, metal and incombustible	8.0%

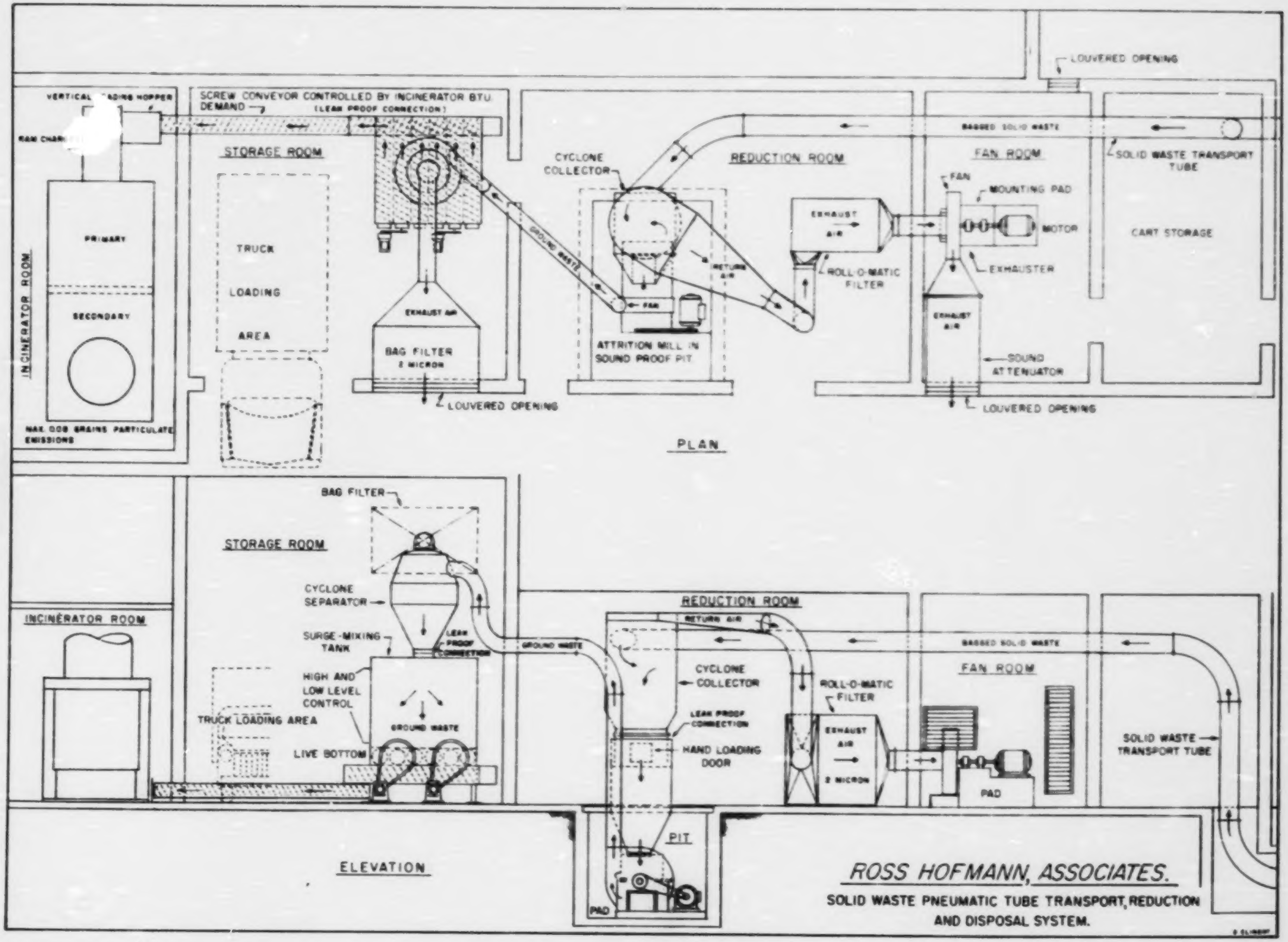
In short, 92 percent of the total is combustible. Further, the density of most hospital waste is lighter than municipal waste. The latter has been estimated to weigh from 5 to 6.3 pounds per cubic foot as against hospital waste in an uncompacted or raw form weighing from 2.5 to 4 pounds per cubic foot, due to the higher quantity of loosely packed and light materials in the total bulk make-up.

Weight reduction during incineration of the hospital waste is greater than with municipal waste, due to the higher percentage of combustibles and is estimated at 85 to 90 percent. Thus a 2,000 pound lot of hospital uncompacted waste measuring approximately 22.5 cubic yards would end up as an ash residue that would weigh approximately 260 pounds. Even more dramatic is the reduction in volume, which is estimated to run as high as 99 percent against the original uncompacted raw waste cube. It is estimated that incinerator residue has a land fill compacted density of 2,700 pounds per cubic yard. Hence the 260 pounds of ash residue would occupy only .097 cubic yards or approximately .44 percent of the original volume.

In connection with incineration, we have a situation with hospitals that should be resolved. Virtually all state and local health codes insist that hospitals maintain a pathological incinerator for the burning and destruction of such specimens. Such units in general do not meet emission standards and hence are endangering the environment, although admittedly the emission volume is quite small in the normal operation of destroying the limited number of pathological specimens that are generated.

Where problems are created is in the case of hospitals being forced to destroy by incineration their other contaminated materials, consisting of large volumes of plastic and paper and other non-pathological matter. In many communities, this has occurred because the local governments have refused to permit such contaminated material being hauled to a landfill due to a fear of affecting the ground water, or for other public health reasons.

Too often we see hospitals that are placed in this position burning these large volumes of such contaminated waste in their pathological incinerator, a device that was never designed for this purpose. The air emissions then become extremely serious and an environmental problem. It would appear more practical to ensure that this is not done; by insisting that such hospitals install environmentally acceptable incinerators of modern design capable of both pathological and general waste burning, and with systems of feeding these that guarantee the desired results.


VERTICAL LOADING HOPPER
RAM CHAR
PRIMARY
SECONDARY
INCINERATOR ROOM
MAX. .008 GRAINS PARTICULATE EMISSIONS
SCREW CONVEYOR CONTROLLED BY INCINERATOR BTU DEMAND
(LEAK PROOF CONNECTION)
STORAGE ROOM
TRUCK LOADING AREA
EXHAUST AIR
BAG FILTER 2 MICRON
LOUVERED OPENING
GROUND WASTE
CYCLONE COLLECTOR
FAN
ATTRITION MILL IN SOUND PROOF PIT
RETURN AIR
REDUCTION ROOM
EXHAUST AIR
ROLL-O-MATIC FILTER
FAN ROOM
FAN
MOUNTING PAD
MOTOR
EXHAUSTER
EXHAUST AIR
SOUND ATTENUATOR
LOUVERED OPENING
BAGGED SOLID WASTE
SOLID WASTE TRANSPORT TUBE
CART STORAGE
LOUVERED OPENING
PLAN
INCINERATOR ROOM
STORAGE ROOM
BAG FILTER
CYCLONE SEPARATOR
SURGE-MIXING TANK
LEAK PROOF CONNECTION
HIGH AND LOW LEVEL CONTROL
TRUCK LOADING AREA
GROUND WASTE
LIVE BOTTOM
GROUND WASTE
REDUCTION ROOM
RETURN AIR
CYCLONE COLLECTOR
LEAK PROOF CONNECTION
HAND LOADING DOOR
ROLL-O-MATIC FILTER
EXHAUST AIR
2 MICRON
BAGGED SOLID WASTE
FAN ROOM
PAD
SOLID WASTE TRANSPORT TUBE
PIT
PAD
ELEVATION

ROSS HOFMANN, ASSOCIATES.

SOLID WASTE PNEUMATIC TUBE TRANSPORT, REDUCTION AND DISPOSAL SYSTEM.

OFF-SITE HAULING VEHICLES

The open waste hauling truck or bin, until a few years ago, was the basic method used for off-site removal. It is generally accepted that if such an open body is used for off-site hauling of only construction and crating materials, such as generated at the loading and receiving dock, that the effects on the environment are not too serious. This assumes a well constructed vehicle with strong sides that is not overloaded. If this same vehicle is used to haul off-site the general solid waste of the hospital, either hand-loaded into it or received from pneumatic transport tubes, this is not acceptable. Too often have we seen such vehicles traveling city streets with red plastic bag loads of hospital waste signifying infectious materials.

A closed off-site hauling vehicle has been studied from several aspects as to its effects on the environment in hauling hospital wastes. As seen from the section on compactors, it is the normal type of trailer used for hauling compacted wastes. Despite the fact that closed vehicles of this type have been seen to leak fluids during a haul to a land fill, the Center for Disease Control states that there has been no documented report of infectious diseases associated with such hauling. Further, it would appear that closed vehicles of this type can be constructed that do not leak.

Waste hauling costs in most metropolitan areas have risen as much as 200 percent in the last 15 years. In cities of 100,000 to 200,000, the price for hauling a 20 to 25 cubic yard compacted load runs from $43 to $48, and a 35 to 40 cubic yard compacted load runs from $46 to $55. The cost of amortizing the compactor and the hauling bin must be added to these figures. This means that hospitals in these smaller communities, with an average census of 350 patients, are paying from $7,000 to $12,500 per year for the hauling of their solid waste. In large Eastern cities, the fees are approximately double this amount.

Obviously every effort should be made to reduce the volume and weight of solid waste the hospital is forced to haul, by the use of compactors, attrition mills, incinerators, and similar devices on a self-liquidating investment basis.

SANITARY LANDFILLS

At present, somewhere in the neighborhood of 80 percent of all hospital waste is hauled to a landfill in an untreated form, with at least 40 percent of the hospitals having first compacted the raw product. Aside from the fact that landfill sites are becoming in increasingly short supply, there is considerable concern as to the effectiveness of the sanitary landfill operation in destroying these wastes so that they do not become a health hazard after burying.

Landfills are accepted by hospitals in much the same manner as they are by other members of the general community. The same attitude applies to the hauling contractors who pick up the solid waste. It usually comes as a shock to investigators surveying hospital solid waste management practices that the hospital personnel, from top administration to middle management, have only a vague idea as to who or what is hauling the waste off-site; where it is being taken; and exactly how it is being handled after it arrives at its destination.

It is essential that all hospitals know where their solid wastes are being hauled off-site; what type of landfill is being used and how it is being managed. While the hospital has no legal jurisdiction over the landfill, it has a moral responsibility to the community to know the type of site to which its contract hauler is transporting the solid waste generated by the institution.

E.P.A. has published guidelines and recommendations for landfill management for several years. The latest are published in the Federal Register for April 27, 1973. In proposed rules for landfill management, paragraph 204.201, "*Solid Wastes Excluded,*" E.P.A. recommends that, "Using information supplied by the waste generator/owner, the responsible agency, the disposal site owner/operator and designer shall jointly determine specific wastes to be excluded and shall identify them in the plans. The generation/owner of excluded wastes and the responsible agency shall jointly determine an alternative method of disposal for excluded wastes. The criteria used to determine whether a waste is unacceptable shall include the hydrogeology of the site, the chemical and biological characteristics of the waste, and the safety of personnel."

SALVAGE, RECYCLING, AND RESOURCE RECOVERY

Studying the habits of hospitals in solid waste disposal indicates that the salvage and recycling practices are used less in hospitals than with industrial plants or homes. There are several apparent reasons for this. The most valuable salvage items are metal scrap of known purity, both ferrous and non-ferrous. Hospitals generate a fairly small amount of metals. A known major waste item that is easily separated from the waste stream would be glass bottles and containers. However, glass has an extremely low recycling rate: only 4.7 percent of the glass produced uses purchased scrap for its make-up.

The amount of worn-out textiles sold by hospitals to salvage operations is difficult to pin down. It is known that clean, uncontaminated, patient and surgical textiles are generated in fairly large quantities by hospitals. However, recycling of textiles has been declining and the market for the hospital product consequently falling. Disposable textile products that are mixed in the solid waste stream are universally destroyed along with the other waste.

Paper and plastics from hospitals have a very low recycling rate. Little effort seems to be spent on salvaging corrugated board, flat board cartons, office and computer paper, newspapers, books and magazines, and packaging paper, despite the fact that paper and cardboard make up 60 percent or better of the total solid waste. Most hospitals seem to feel that the expense of segregating this part of the waste, even though clean and uncontaminated, is much more than they can realize from sale to salvage dealers.

Plastics generated as waste in hospitals are the same type as generated by homes, stores, and other institutions. Sale as salvage, with present technology for recycling, is not practical, due to the tremendous number of different chemical formulations used. This makes it impossible to sort these into like formulations after use; without such sorting little practical use can be made of the product.

The net result of the above considerations is that hospitals and the community are left by and large with most of the solid waste that was generated. Very few saleable materials are diverted from the waste stream. The only potential resource recovery is to use the waste as energy; to possibly convert it to a fuel under a method that will at least recapture the cost of burning it, and hopefully at least part of the cost of collecting, transporting, and processing it.

It has been discovered that municipal solid waste is a clean fuel from the point of view of environmental pollution. Several European municipal plants, over the past years, plus a few in Canada and the United States recently, have used solid waste as a fuel in special boilers for steam generation. Hospital solid waste mixtures, as seen in the section on incineration, have a relatively high B.T.U. output, and if ground, or milled, and mixed, have a fairly consistent B.T.U. output. Further, the moisture content is much lower than in municipal waste and also much more consistent, thus reducing a major problem in using solid waste as an efficient fuel.

Hospitals are also heavy users of steam for heating and sterilization. A few are now investigating the potential of capturing the heat generated during their in-house incineration and putting it to use. The systems are still in the experimental phase and it is not known how successful the economics will prove to be. The technology would be similar to that used in certain municipal incinerator plants, and in some industrial operations, but on a much smaller scale.

What is yet to be determined is whether the waste generated by even the largest hospitals (500 beds and over) is sufficient to operate an economically feasible waste heat recovery system.

In municipal plants, successful waste heat recovery systems appear to involve a 24-hour-a-day operation and a relatively constant burning of waste during this period. Hospital incinerators usually do not operate over 12 hours, and normally for far shorter periods. Hence the technology of heat storage must be quite different from that of municipal systems. To date, experimentation in hospitals has concentrated on piping superheated water or other fluids from the incinerator to remote storage and heat exchangers, rather than the direct production of steam at the incinerator or an adjacent boiler.

It would appear that further engineering and economic research on the use of waste heat recovery systems in hospitals would be worthwhile and might offer a definite economic return for the design effort expended.

The solution to using the heat of the gases from hospital incinerators for waste heat recovery, as pointed out above, must follow a slightly different technical direction than with municipal waste. There are three main reasons for this:

(a) While both municipal and hospital wastes are relatively "clean" fuels, hospital waste has a higher plastic content. This means that the incinerator used must be capable of handling plastics in quantity. Also it means that the effluent gases are more corrosive from hospital waste and hence the waste heat recovery boiler linings, diverter valves, and tubes must be constructed of materials that will not corrode quickly from the gas.

(b) Hospital waste in medium sized institutions rarely is burned at rates greater than 1,500 pounds per hour and the average is closer to 1,000 pounds per hour. Burning times rarely exceed 12 hours per day and the average is closer to 6 hours per day.

(c) Due to the limited total quantity of waste and short burning hours, either waste heat storage systems must be developed (such as hot water storage in tanks), or the waste heat must be used first as an auxiliary to the main steam supply and for limited use.

5-DESCRIPTION OF THE SURVEY HOSPITALS

To determine the feasibility of pneumatic waste transport systems in hospitals, three institutions were selected that would give a good cross section of medium sized hospitals, their solid waste management practices, as well as types of pneumatic equipment currently in use. The institutions selected were the Veterans Administration Hospital, San Diego, California; Martin Luther King Hospital, Los Angeles, California; and St. Mary's Hospital, Duluth, Minnesota.

ST. MARY'S HOSPITAL, DULUTH, MINN.

St. Mary's Hospital, owned and operated by the Benedictine Sisters Benevolent Association, is a 495-bed acute general hospital. During the past year, the average rate of occupancy has been 79.8 percent on an active 419 registered beds for adults and children, giving a daily census of 335 patients.

During the survey period, the admissions per day were 42 and the discharges 44, with an average length of stay for each patient of 7.5 days.

There were 44 outpatient visits and 48 emergency visits to the hospital per day.

The total hospital staff, on a full-time equivalent basis, was 1,033, giving a total hospital population (inpatient, outpatient, staff) of 1,460 daily.

The ancillary and support activities can be seen from the following statistics of activity during the survey period for daily averages:

Meals served ... 1,743
Laboratory tests for both inpatients and outpatients ... 1,085
Operating Room procedures for inpatients and outpatients ... 31
Radiology procedures for inpatients and outpatients ... 198
Pounds of laundry handled per day ... 6,841

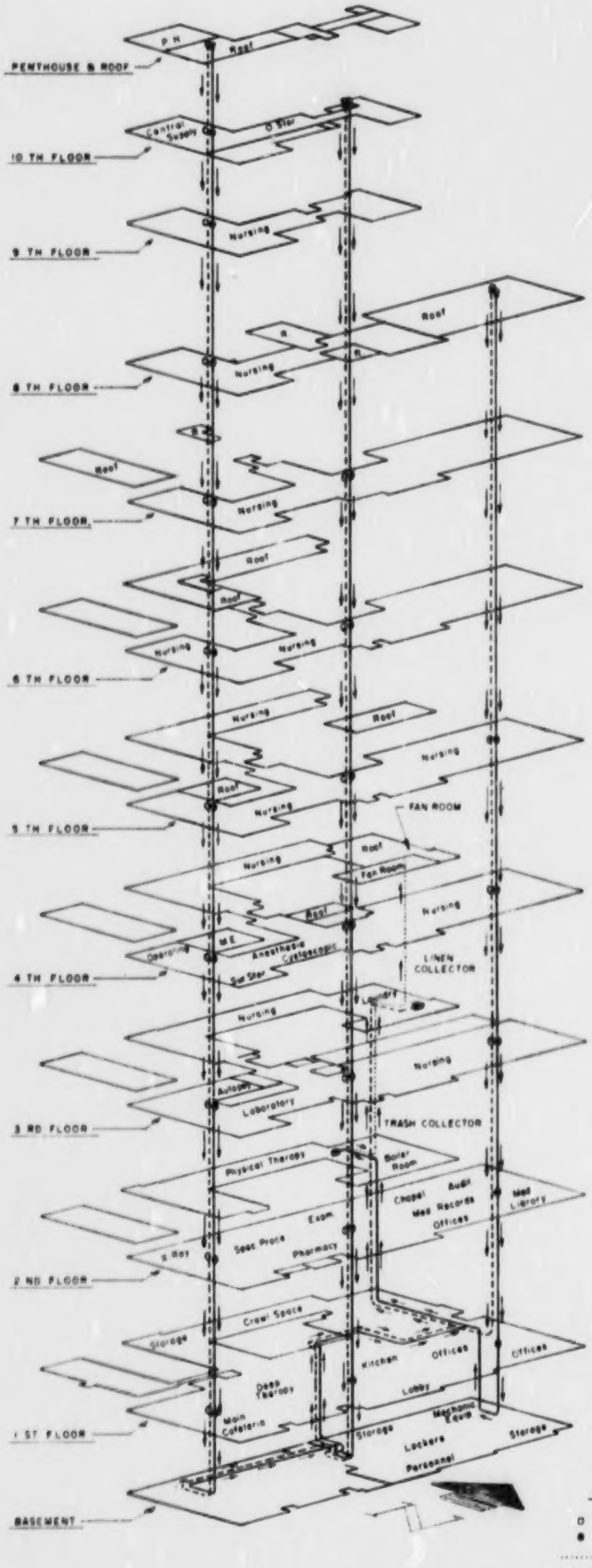
The building complex consists of 518,853 total square feet, of which

451,530 is maintained by the housekeeping department. The basic design consists of a West Wing that is ten stories high, a Center Wing that is ten stories high, an East Wing that is seven stories high, a North Wing that is connected to the Center Wing by a corridor and is five stories high, and a Service Building housing the laundry, boiler plant, and waste collection room, connected to the North Wing, and having a total height of three stories.

The pneumatic trash and linen system was designed by the vendor and installed in two phases. The first phase, covering the East and Center Wings, was completed in October of 1969 for a cost of $109,357. The second phase of the system was installed complete in January of 1971 at an additional cost of $73,800. The two phases resulted in a complete system for the hospital comprising 41 load stations, of which 20 are for linen and 21 are for waste, with three vertical pairs of chutes (one for waste and one for linen), one for the West Wing, one for the Center Wing, and one for the East Wing.

The system that is used is a full-vacuum 16 in. diameter tube with 20 gauge wall system, with separate loading doors and separate chutes for waste and laundry, and operates on the "single bag" method with no multiple loading of bags. The chute loading stations are located in chute rooms.

As can be seen from the statistics in the next chapter, approximately 38.8 percent by weight and 67.4 percent by volume of the total waste of the hospital is sent through the pneumatic system. The balance of the items, that are either too bulky, or consist of glass and metal cans, are removed by cart by the housekeeping department during regular "sweeps" of the building over a 17 hour period each day. The pneumatic waste system operates from 5:00 A.M. to 10:00 P.M. The cart removal of waste operates during the same time period, plus additional hauling during the night hours from public lobbies and the Emergency Room.


PENTHOUSE & ROOF
P H
Roof
10 TH FLOOR
Central Supply
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Nursing
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LINEN COLLECTOR
Laundry
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Nursing
Nursing
Autopsy
Laboratory
TRASH COLLECTOR
2 ND FLOOR
Physical Therapy
Boiler Room
X Ray
Spec Proce
Exam
Pharmacy
Chapel
Audit
Med Records
Offices
Med Library
1 ST FLOOR
Storage
Crawl Space
Deep Therapy
Main Cafeteria
Kitchen
Offices
Offices
Lobby
Mechanical Equip
BASEMENT
Storage
Lockers
Personnel
Storage

LEGEND

- ○ LINEN STATION
- ● TRASH STATION
- .... AIR RETURN LINE
- _ _ _ _ LINEN LINE
- ——— TRASH LINE

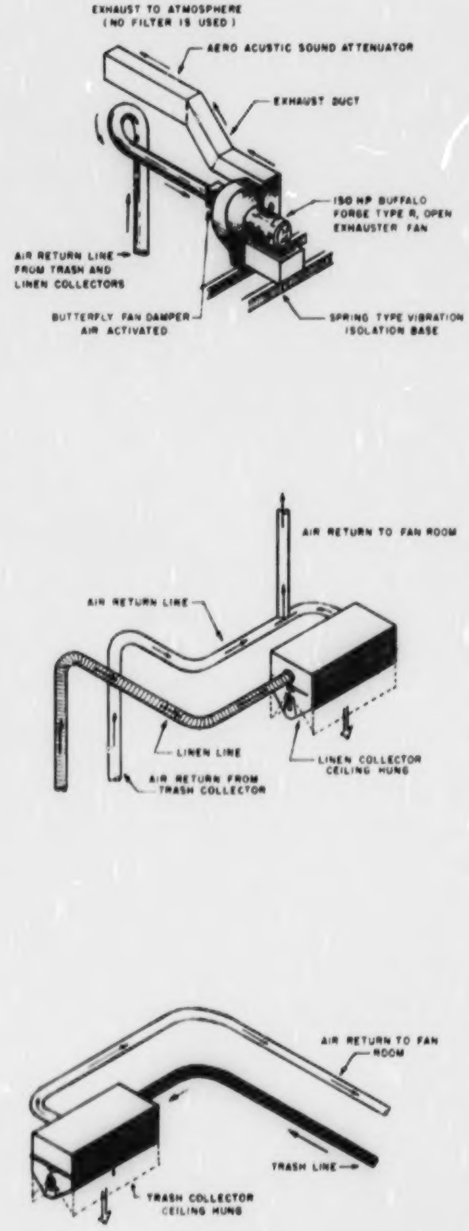

EXHAUST TO ATMOSPHERE (NO FILTER IS USED)
AERO ACUSTIC SOUND ATTENUATOR
EXHAUST DUCT
150 HP BUFFALO FORGE TYPE R, OPEN EXHAUSTER FAN
AIR RETURN LINE FROM TRASH AND LINEN COLLECTORS
BUTTERFLY FAN DAMPER AIR ACTIVATED
SPRING TYPE VIBRATION ISOLATION BASE
AIR RETURN TO FAN ROOM
AIR RETURN LINE
LINEN LINE
AIR RETURN FROM TRASH COLLECTOR
LINEN COLLECTOR CEILING HUNG
AIR RETURN TO FAN ROOM
TRASH LINE
TRASH COLLECTOR CEILING HUNG

FIGURE 8

ST MARY'S HOSPITAL

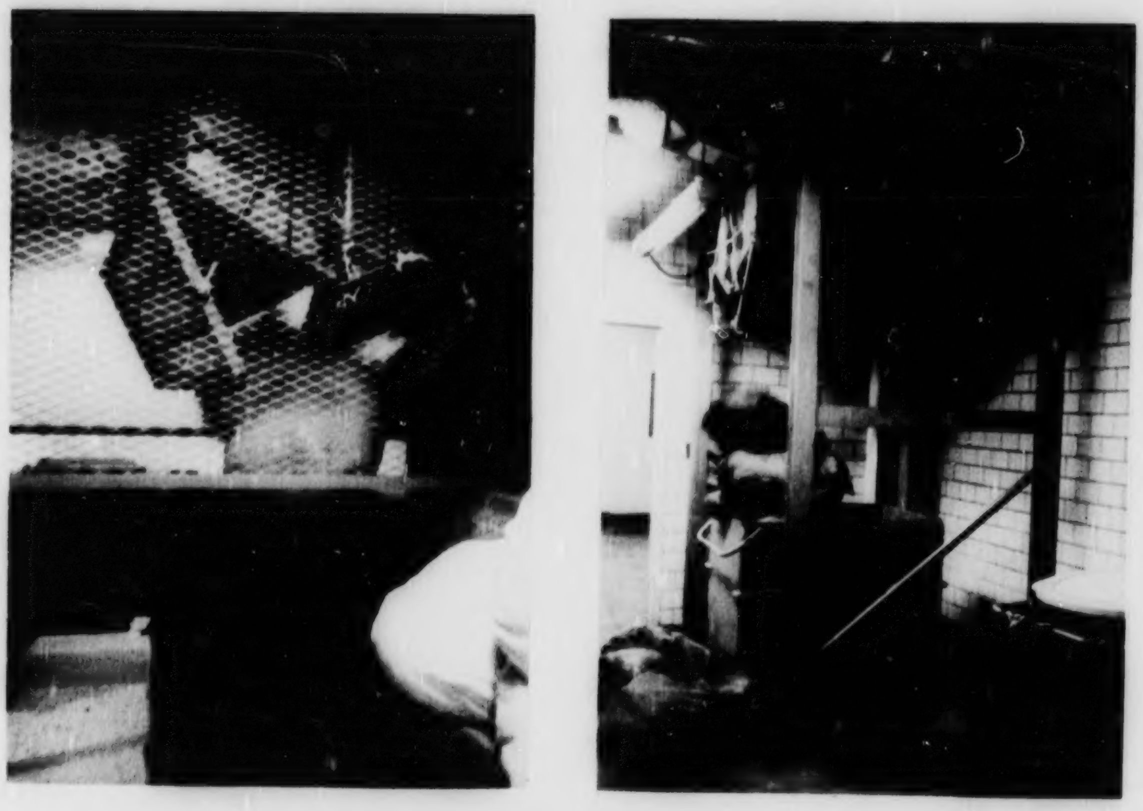
Duluth-Minnesota

PNEUMATIC TUBE SYSTEM FOR
SOLID WASTE & LAUNDRY

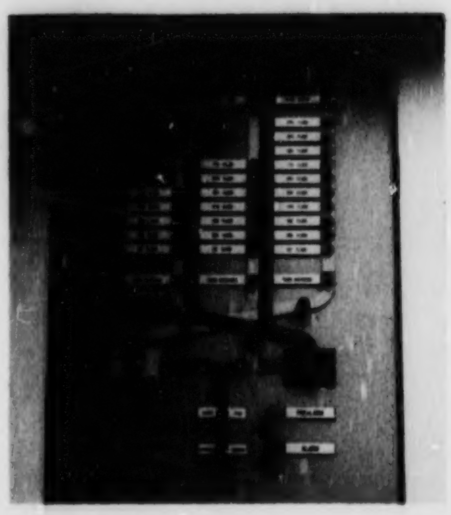
Loading the single bag, full vacuum system at St. Mary's Hospital.

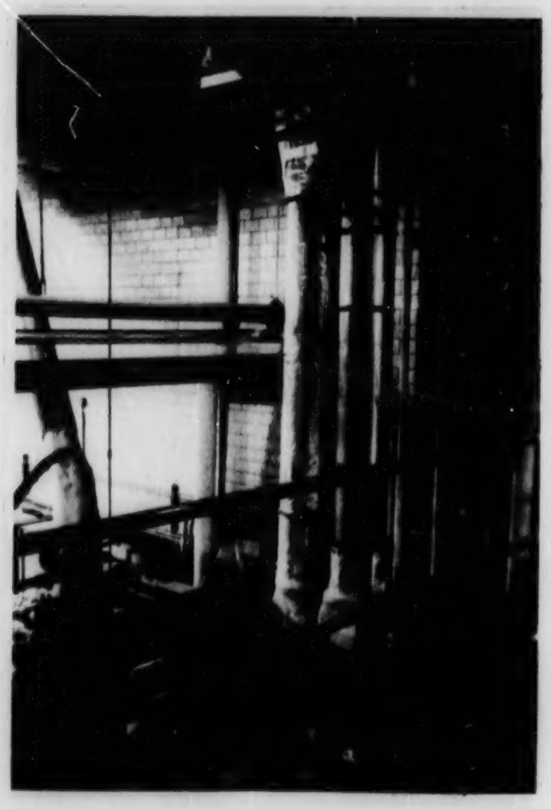
During peak periods in busy nursing wings single bag systems rarely can keep up with the speed waste is generated, as seen by the above view of typical chute room.

Lower left: these nylon mesh bags virtually eliminate bag breakage and hence environmental problems in this system.



Above: Views of the box type soiled laundry and solid waste collectors at the end of the line at St. Mary's Hospital. The waste must be hand carted from the waste collector to the compactor located in the Service Building court yard.





Above: The Engineering Department of St. Mary's designed and installed a unique monitoring panel to determine the status of any loading station.

Right: Typical tubing rising from the basement into the Service Building.

Left: The fan room equipment is unsophisticated and quite lightly constructed in this system, using an open type materials handling fan and a simple exhaust duct type sound attenuator. High level vacuum protection is obtained by a gate valve before the fan.

VETERANS ADMINISTRATION HOSPITAL, SAN DIEGO, CALIFORNIA

The Veterans Administration Hospital, located in La Jolla, a suburb of San Diego, California, is owned and operated by the Veterans Administration of the United States Government. It is a 811-bed general hospital which, during the past year, has experienced an average rate of occupancy of 59.0 percent on an active 646 registered beds, giving an average daily patient census of 400.

During the survey period, the number of admissions per day was 29.4 and the discharges were 30.3, with an average length of stay for each patient of 11.5 days. There were 199 outpatient visits per day. Emergency visits, as found in community hospitals, do not occur.

The total hospital staff, on a full-time equivalent basis, consisted of 1,605 people daily, giving a total hospital population (inpatients, outpatients and staff) average of 2,204 daily.

The various support activities of this hospital can be seen from the following daily average statistics gathered during the survey period:

Meals served . . . 2,380

Laboratory tests, in- and outpatient . . . 4,936

Radiology procedures . . . 165

Operating Room procedures . . . 24

Pounds of laundry . . . 136,848

The hospital has 677,700 gross square feet of enclosed area, consisting of the penthouse, six floors, a basement, and a mechanical room above the penthouse. Above the first floor, the building is laid out as a cross, with North, East, South and West wings intersecting in the center, with a loading dock at the far end of the North wing. The cost of construction was approximately $35,250,000.

The pneumatic trash and linen system was installed in November 1971, at a cost of $350,000. It is a full-vacuum, single tube system, for moving both waste and laundry. The tube is 16 in. in diameter with 20 gauge wall, and there are a total of 54 load stations--27 for waste and 27 for laundry. The system is key-lock operated and permits one operator to deposit 10 to 12 bags of laundry and up to 12 bags of waste on a continuous loading basis, one station at a time.

As can be seen from the statistics in the next chapter, approximately 25.1 percent by weight and 35.4 percent by volume of the total waste of the hospital is sent through the pneumatic system. The balance of the items are either too bulky, or consist of glass and metal cans, or are deemed infectious or hazardous. They are removed by cart using an average of 31 cart trips per day. The pneumatic waste system operates from 6:00 A.M. to 3:30 P.M.

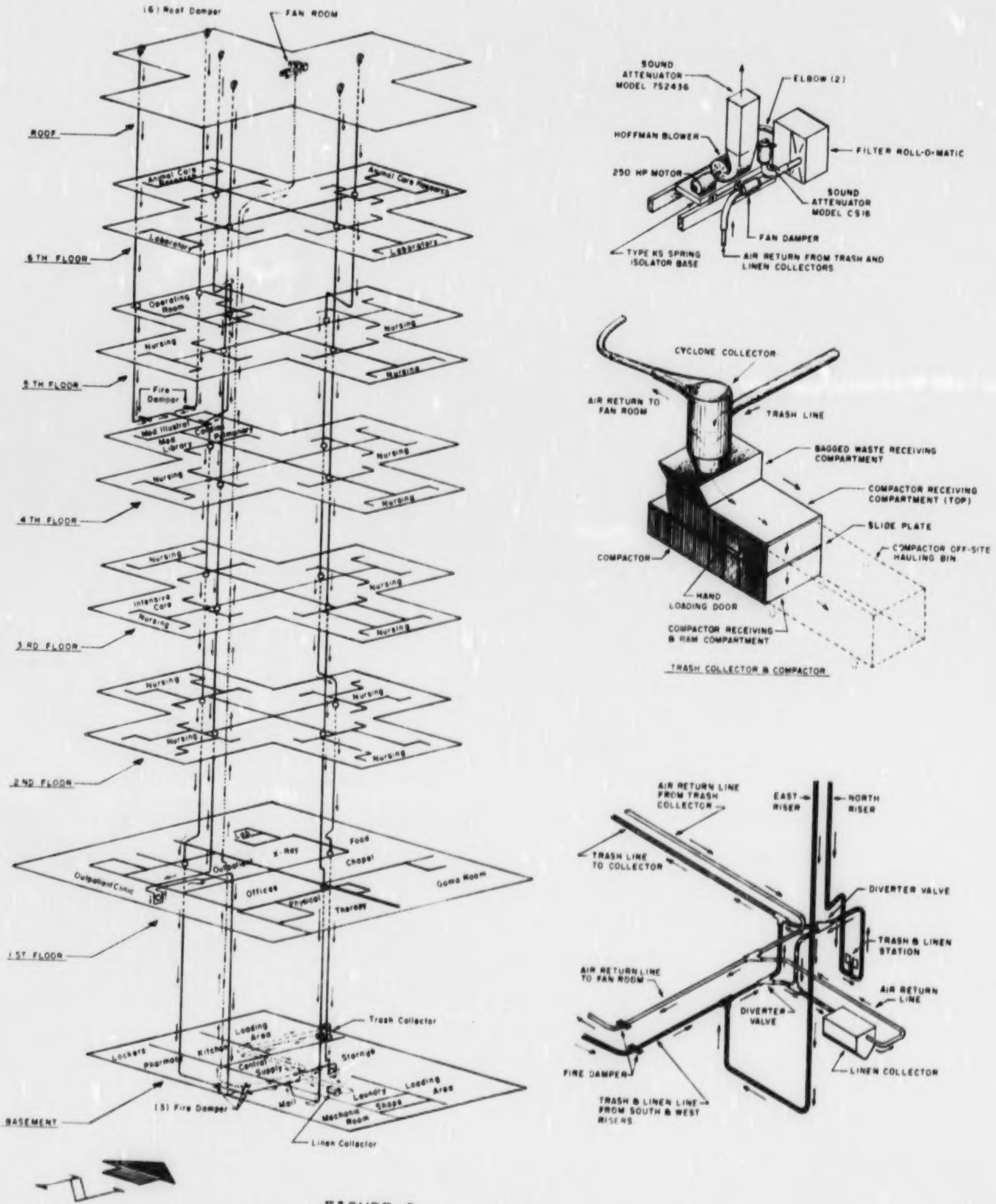
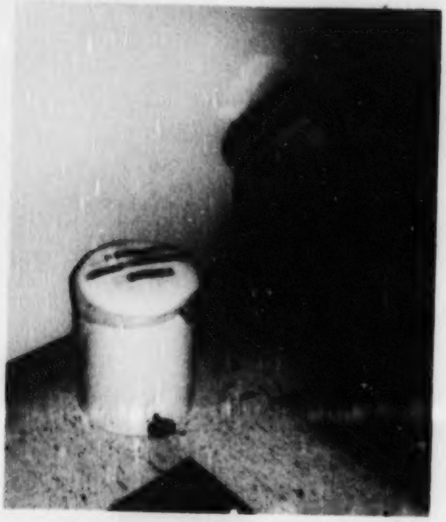
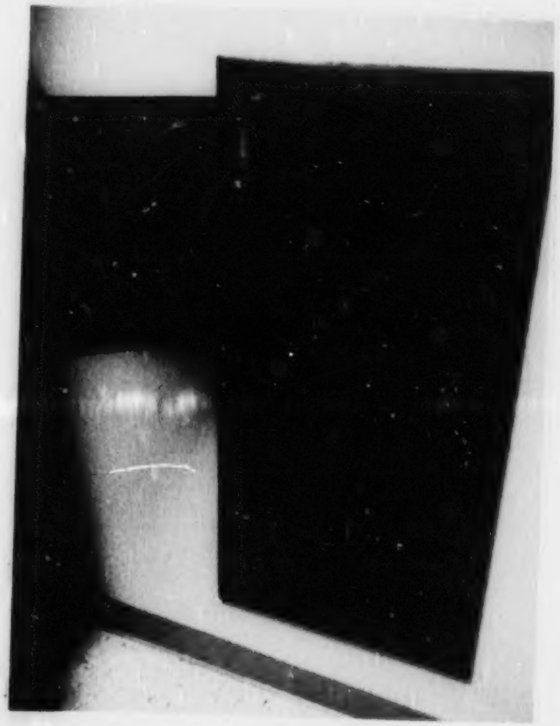

(6) Roof Damper
FAN ROOM
ROOF
Animal Care Research
Animal Care Research
Laboratory
Laboratory
6TH FLOOR
Operating Room
Nursing
Nursing
Nursing
5TH FLOOR
Fire Damper
Med Illustrat
Med Library
Central Personnel
Nursing
Nursing
Nursing
4TH FLOOR
Nursing
Intensive Care
Nursing
Nursing
Nursing
3RD FLOOR
Nursing
Nursing
Nursing
Nursing
2ND FLOOR
X-Ray
Food
Chapel
Outpatient
Outpatient Clinic
Offices
Physical Therapy
Game Room
1ST FLOOR
Trash Collector
Loading Area
Lockers
Pharmacy
Kitchen
Control
Supply
Storage
Laundry
Loading Area
Mail
Shops
Mechanical Room
(5) Fire Damper
BASEMENT
Linen Collector
SOUND ATTENUATOR MODEL 752436
ELBOW (2)
HOFFMAN BLOWER
FILTER ROLL-O-MATIC
250 HP MOTOR
SOUND ATTENUATOR MODEL CS16
FAN DAMPER
TYPE KS SPRING ISOLATOR BASE
AIR RETURN FROM TRASH AND LINEN COLLECTORS
CYCLONE COLLECTOR
AIR RETURN TO FAN ROOM
TRASH LINE
BAGGED WASTE RECEIVING COMPARTMENT
COMPACTOR RECEIVING COMPARTMENT (TOP)
SLIDE PLATE
COMPACTOR OFF-SITE HAULING BIN
COMPACTOR
HAND LOADING DOOR
COMPACTOR RECEIVING & RAM COMPARTMENT
TRASH COLLECTOR & COMPACTOR
AIR RETURN LINE FROM TRASH COLLECTOR
EAST RISER
NORTH RISER
TRASH LINE TO COLLECTOR
DIVERTER VALVE
TRASH & LINEN STATION
AIR RETURN LINE TO FAN ROOM
AIR RETURN LINE
DIVERTER VALVE
FIRE DAMPER
LINEN COLLECTOR
TRASH & LINEN LINE FROM SOUTH & WEST RISERS
LEGEND
• TRASH & LINEN STATION
TRASH & LINEN LINE
TRASH LINE
LINEN LINE
AIR RETURN
LEGEND
TRASH & LINEN LINE
TRASH LINE
LINEN LINE
AIR RETURN
D CLIMENT

FIGURE 9

VETERANS ADMINISTRATION HOSPITAL
San Diego .... California

PNEUMATIC TUBE SYSTEM FOR
SOLID WASTE & LAUNDRY



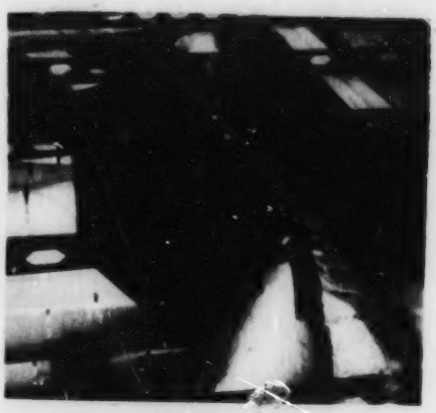


The Veterans Administration Hospital is noted for its excellent housekeeping practices.

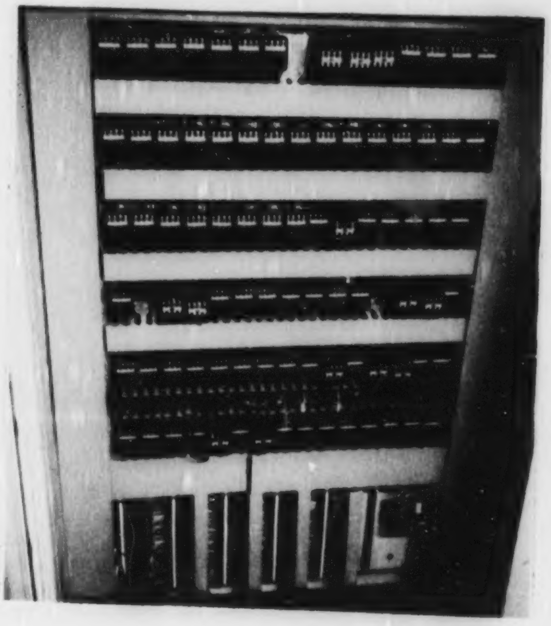
Above: Special color coded and labeled containers with distinctively colored plastic bag liners for the glass and metal waste.

Top: The loading hopper of a typical waste chute.

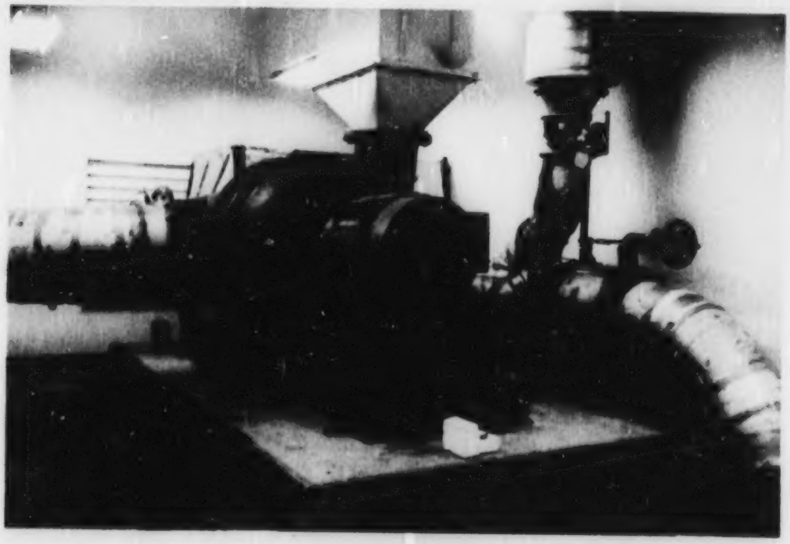
Left: This collection of bags of solid waste was assembled to determine the speed of loading in this multiple bag system. The 28 bags in the pile were dispatched in under two minutes.



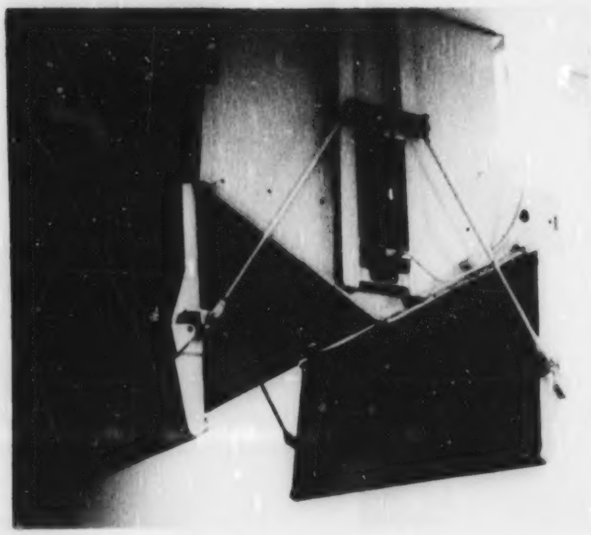
The Veterans Administration Hospital utilizes a single tube system. Above is the Diverter Valve Box designed to divert waste or laundry to the proper collector.



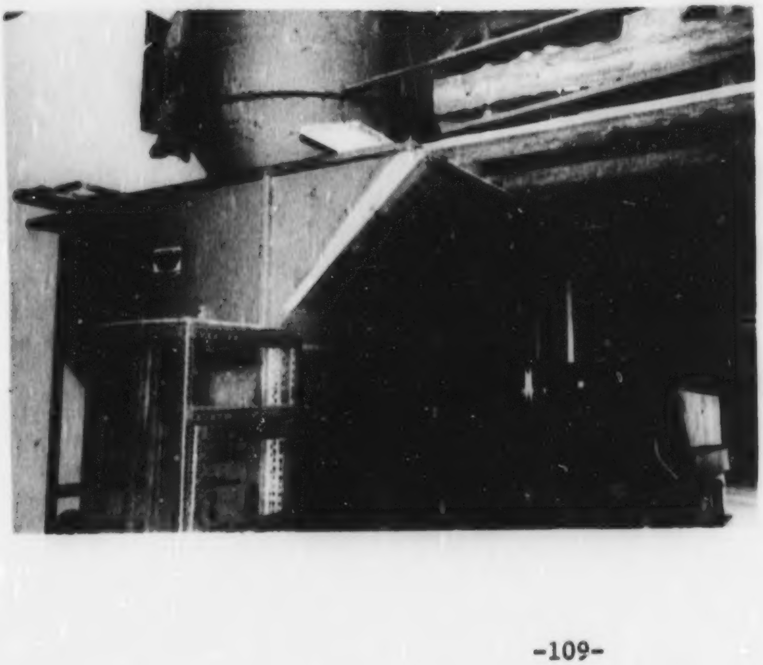
Above right: The control panel of this system consists of a series of stepping relays to activate the various roof dampers, inner chute doors, diverter valve, collector box doors, etc. The entire system requires several miles of wiring, making the electrical hook-up one of the most costly elements in the installation.



Left: The fan room is located in a penthouse atop the hospital. The fan has an excellent vibration dampener base. The Rollomatic filter to protect the fan can be seen at the rear, with the high vacuum relief system to the right of the fan motor.



At the Veterans Administration Hospital two totally different styles of collectors are used. Top right is the square, box type, laundry collector dropping into the soiled laundry receiving section.



Top left and lower left: The cyclone collector used for waste is designed to receive rapid and continuous loading. Note that most bags are ripped by the time they emerge from the collector. The entrance to the compactor is not close coupled to the collector and presents serious aerosol possibilities with broken bags.

MARTIN LUTHER KING HOSPITAL, LOS ANGELES, CALIFORNIA

Martin Luther King Hospital, owned and operated by Los Angeles County, is a 394-bed general hospital. During the past year, the average rate of occupancy has been 64.4 percent on an active 320 registered beds for adults and children, giving a daily census of 206 patients, including bassinets.

During the survey period, the admissions per day were 28 and the discharges were 38, with an average length of stay of 7.7 days.

The hospital operates a large outpatient department, averaging 360 visits daily, and an equally large emergency service, averaging 218 visits daily.

The total hospital staff, on a full-time equivalent basis, was 2,200 people daily.

The ancillary and support activities can be seen from the following statistics of activities during the survey period for daily averages.

Meals served . . . 1,519

Laboratory tests for both inpatients and outpatients . . . 4,341

Major surgical procedures . . . 6

Minor surgical procedures . . . 9

Radiology procedures for inpatients and outpatients . . . 157

Pounds of laundry handled per day . . . 9,524

The building complex consists of 551,251 square feet and includes six floors plus a basement. It was constructed for a total cost of $23,540,000. The pneumatic waste and laundry system was installed in March 1972. The system is a gravity to vacuum type, utilizing 14 gauge 20 in. diameter gravity chutes and 20 in. vacuum tubes of heavy wall pipe, operating on a key-lock, multiple bag principle. The use of gravity chutes means there is no limit on the number of bags that can be loaded by a single operator. There are 43 loading stations total, of which 19 are for laundry only and 24 are for waste only. The system includes four vertical tubes for laundry and four for waste. The cost of the installation was $425,000. The system operates on a 24 hour day basis. Approximately 60 percent by weight and 85 percent by volume of the total solid waste is transported by the system.

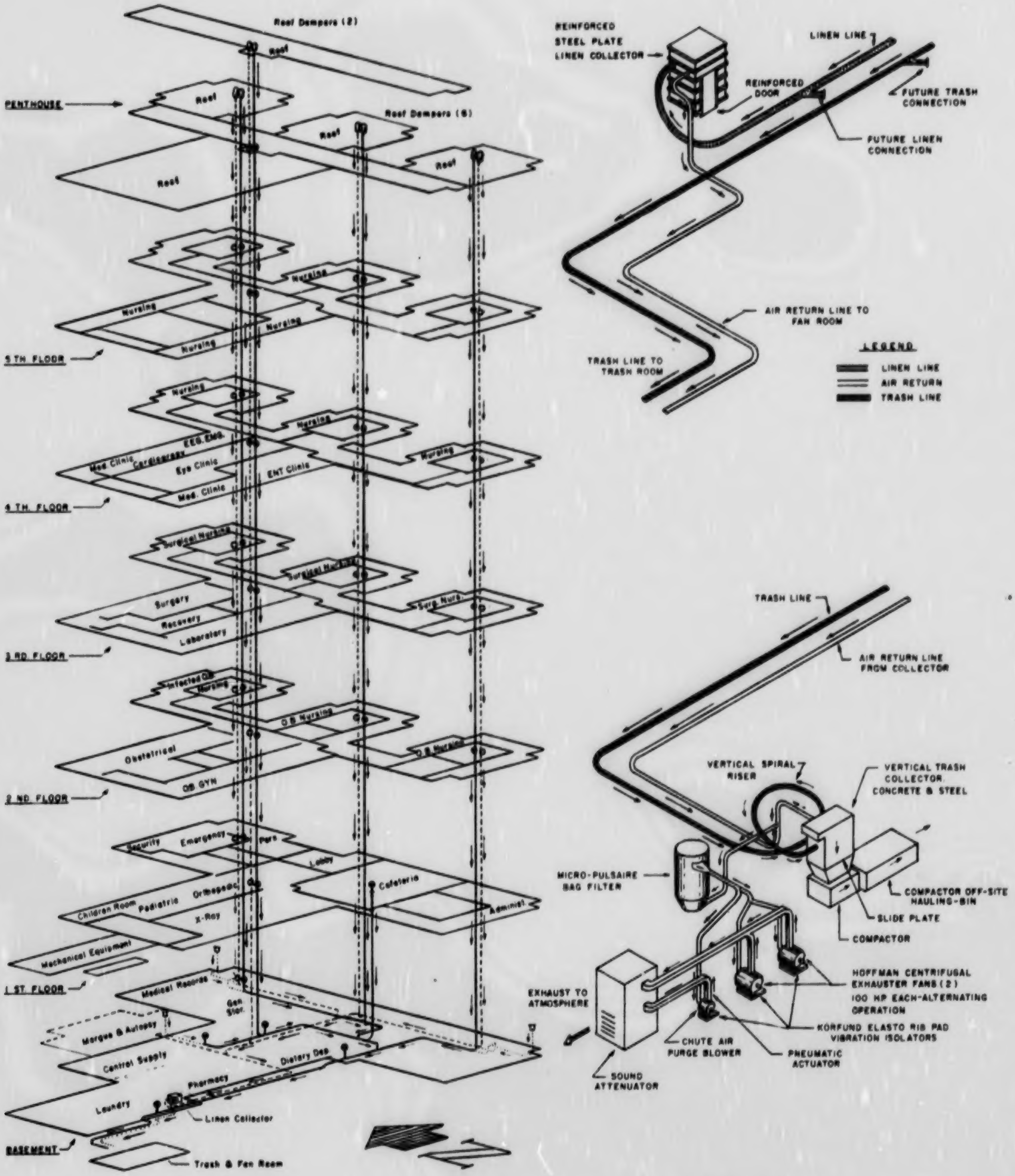

Roof Dampers (2)
Roof
PENTHOUSE
Roof
Roof Dampers (6)
Roof
Roof
Roof
Nursing
Nursing
Nursing
Nursing
5 TH FLOOR
Nursing
Nursing
EEG. EMG.
Med Clinic
Cardiology
Eye Clinic
ENT Clinic
Nursing
Med. Clinic
4 TH. FLOOR
Surgical Nursing
Surgical Nursing
Surgery
Recovery
Surg. Nurs.
Laboratory
3 RD FLOOR
Infected OB Nursing
O B Nursing
O B Nursing
Obstetrical
OB GYN
2 ND FLOOR
Security
Emergency
Pers
Lobby
Cafeteria
Orthopedic
Children Room
Pediatric
X-Ray
Adminst.
Mechanical Equipment
1 ST. FLOOR
Medical Records
Gen. Stor.
Morgue & Autopsy
Central Supply
Dietary Dep.
Pharmacy
Laundry
Linen Collector
BASEMENT
Trash & Fan Room
REINFORCED STEEL PLATE LINEN COLLECTOR
LINEN LINE
REINFORCED DOOR
FUTURE TRASH CONNECTION
FUTURE LINEN CONNECTION
AIR RETURN LINE TO FAN ROOM
TRASH LINE TO TRASH ROOM
LEGEND
LINEN LINE
AIR RETURN
TRASH LINE
TRASH LINE
AIR RETURN LINE FROM COLLECTOR
VERTICAL SPIRAL RISER
VERTICAL TRASH COLLECTOR CONCRETE & STEEL
MICRO-PULSAIRE BAG FILTER
COMPACTOR OFF-SITE HAULING-BIN
SLIDE PLATE
COMPACTOR
HOFFMAN CENTRIFUGAL EXHAUSTER FANS (2)
100 HP EACH-ALTERNATING OPERATION
EXHAUST TO ATMOSPHERE
KORFUND ELASTO RIB PAD VIBRATION ISOLATORS
CHUTE AIR PURGE BLOWER
PNEUMATIC ACTUATOR
SOUND ATTENUATOR
LEGEND
AIR INTAKE
LINEN STATION
TRASH STATION
AIR RETURN LINE
LINEN LINE
TRASH LINE

FIGURE 10

MARTIN LUTHER KING HOSPITAL
Los Angeles California

PNEUMATIC TUBE SYSTEM FOR
SOLID WASTE & LAUNDRY

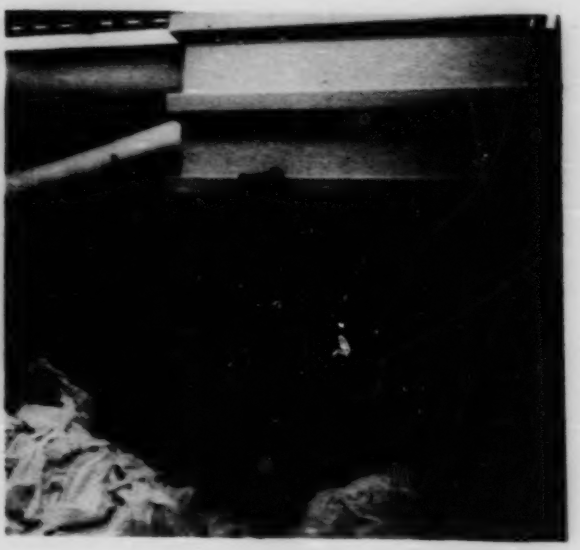
NO GLASS OR LIQUID
TRASH MUST BE IN
MAXIMUM SIZE OF BAG
NO BOXES

MARTIN LUTHER KING

The photograph above shows the different configurations used for the loading hoppers of the Laundry and Waste chutes. The administration constantly reminds the personnel against overloading the chutes or transporting breakables.

For basement and first level loading stations, independent of the 6-story high vertical chutes, hydraulic operated hoppers, as shown above, are used.

(Left) View of a typical slide valve, separating the vertical gravity chute from the pneumatic horizontal tube system.

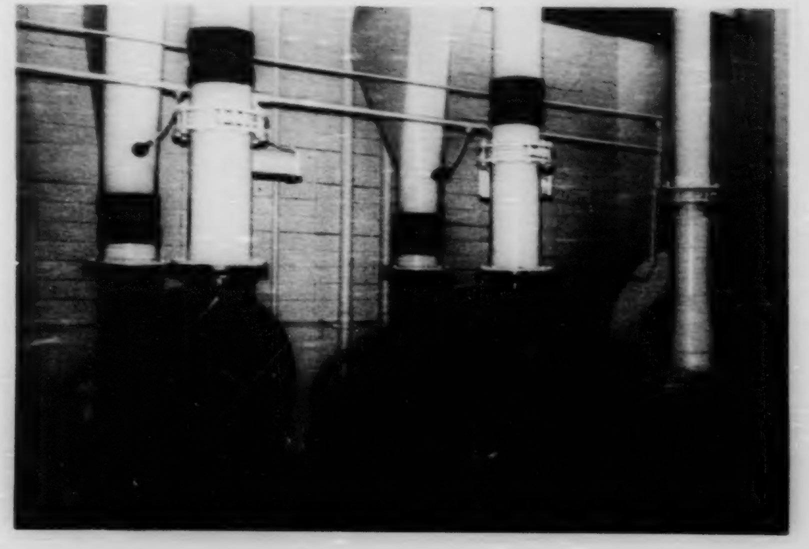


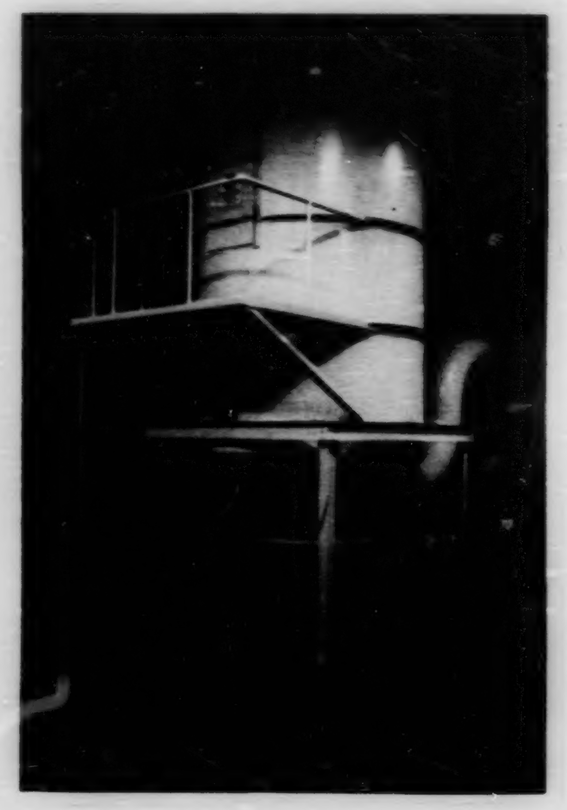
All equipment items in the Martin Luther King system are constructed ruggedly.

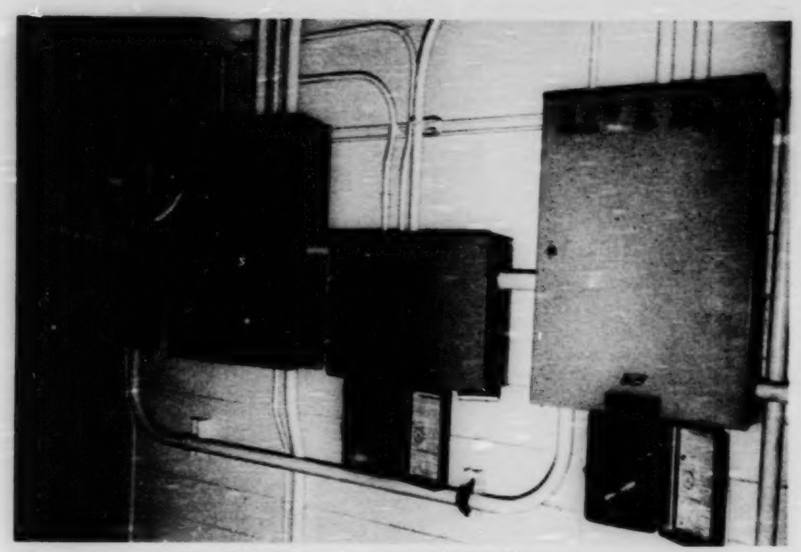
Top right: The soiled laundry collector is virtually a room in itself. Note the heavy reinforced plate construction.

Top left: The compactor bin is located in an air conditioned storage room and large enough to hold a five-day waste supply.

Lower left: The compactor is close-coupled to the concrete and steel waste collector bin.







Three views of the Mechanical-Fan room at Martin Luther King, showing the excellent quality of the equipment.
Top left: The alternating exhaust fans.
Top right: The 2 micron bag filter installed to prevent fan damage and environmental problems. Lower left: The control and monitoring panel.

6-QUANTITIES AND TYPES OF HOSPITAL SOLID WASTE

To determine the quantities of waste generated by hospitals, numerous surveys were made during the present study, with in-depth analyses of the three pilot hospitals. The figures were compared with those the researchers had obtained from other hospital solid waste studies. The surveys approached the analyses from several directions. These included weighing and measuring each individual bag transported through the pneumatic tube system, together with all waste hand-hauled by cart, over a complete 24 hour period for seven days in a row. Breakdowns were obtained for each hour of the day, each day of the week, by each generating point in the building. Analysis was made of the types of waste generated from all points. Total figures were checked against totals revealed in the central collection area.

TOTAL WASTE GENERATED BY THE SURVEY HOSPITALS

The three pilot institutions represent a fair cross section of American hospitals, with a census from 190 to 400, a total population of staff and patients from 920 to 2,000, and outpatient-emergency visits from 90 to 580 per day. Each was quite different in type of patient and medical delivery program, ranging from the "typical" community hospital of a medium sized city, to an urban area hospital with county ownership, to a hospital with research and teaching programs. However, it should be pointed out that three hospitals are too small a sample to be representative of the American hospital system for the purpose of establishing hospital waste loads on a broad basis.

Other surveys performed by the consultant[1] reveal that, currently, hospital waste loads based on total hospital population (patients plus staff) vary as much as 60 percent. As may be expected, the more sophisticated the health delivery and research, and the larger the metropolitan area in which the hospital is located, the larger the waste load. This should not be surprising when one considers that a major metropolitan daily newspaper weighs as much as 1.5 lb, which, if brought into the hospital by and for every member of the total population (staff and patients) plus a percentage of visitors, would have the affect of almost doubling the hospital waste load.

Waste from food preparation and from scrapings of plates from the cafeterias and snack bars was disposed of through kitchen garbage grinders into the sewer system in all three hospitals. Thus it does not appear in the waste delivered at the central collection point to be hauled off-site. As it was impossible to weigh all such food waste without disrupting kitchen activities, sampling techniques were used.

From this it is estimated that in a combination of food preparation and in plate food scraping before dishwashing, an average of 0.21 lb of such waste per meal served was generated between the three pilot hospitals.

No "outside yard" or construction wastes were included in the total waste figures unless they were taken to the central collection point and hauled off-site with the waste generated in the building. This applies to lawn cuttings. In the only construction observed during the survey period, the general contractor removed his own waste.

In the survey of the wastes at the three pilot hospitals, detailed analyses were made of the total weights and cubes generated by the material transported from the floors to the central collection point. These cover a period of seven consecutive days and all three shifts for each 24 hour day. The surveys were conducted during July, August, and September of 1973.

RATIOS OF WASTE TO HOSPITAL POPULATION SEGMENTS AND UTILIZATION

When hospital wastes are compared on the basis of combining inpatient census with outpatient visits and total staff (total full time equivalent of a 24 hour population); and reviewed along with the activities of the ancillary departments that are large waste producers; then direct comparisons can be made between hospitals; and between hospitals and other segments of the economy.

Other surveys of hospitals in major metropolitan areas indicate that 10.0 to 10.4 lb per occupied bed appears valid for many hospitals.[2] The average of 11.3 lb per occupied bed in the current study is high. The average of 9.2 lb per occupied bed obtained by totaling St. Mary's and the Veterans Administration Hospitals is a fairly representative figure. When Martin Luther King is added, with its heavy outpatient and E.R. load and the extremely large staff of 2,200 people handling only 183 occupied beds, the amount of waste per bed becomes biased.

The importance of factoring waste against the "full time population" of the hospital can be seen from a review of the statistics in Table 4. Figuring the waste generated against the total population of the hospital more clearly shows the valid differences between institutions regardless of scope of work or staffing patterns used.

"Full time population" of a hospital is a term that is not well understood by many people. First, it consists of the average daily inpatient census, rather than the total bed complement that is available. Average daily inpatient census varies considerably between hospitals (anywhere from 45 percent to 95 percent of the total available beds). Secondly, it includes the ambulatory patients that each day visit the outpatient clinics and emergency service. Each patient is recorded as a single "visit" in the total population, even though he may be treated in more than one clinic. Thirdly, the population includes the "full time equivalent" staff of the hospital, both paid and non-paid or volunteer. This staff varies by shift and drops off on weekends. First shift, from 8:00 A.M. to 4:00 P.M., may have two or three times the staff of the 4:00 P.M. to midnight and the midnight to 8:00 A.M. "Full time" equivalent becomes a weighted average of the staff population of the three shifts.

Each person in the total population is a contributor to the waste load. The contribution of each person varies with his or her activities and the hours present in the hospital. As the staff is the largest single block in the total population, and as the staff varies considerably with the three shifts, as do outpatient visits, the waste varies similarly by shift and between weekdays and weekends, often as much as over 50 percent.

TABLE 4

RATIOS OF SOLID WASTE
TO HOSPITAL POPULATIONS, ACTIVITIES & FLOOR SPACE

ITEM	ST. MARY'S HOSPITAL	V.A. HOSPITAL	MARTIN LUTHER KING HOSPITAL
Average Total Waste per Day:			
Pounds	2273	4445	3678
Cubic Feet	567	1575	1188
Total Number of Available Beds	419	646	320
Average Occupancy Rate During Period	79.8%	61.9%	64.4%
Average Number of Occupied Beds	335	400	183
Quantity of Waste Per Occupied Bed:			
Pounds	6.8	11.1	20.1
Cubic Feet	1.7	3.9	6.5
Average Daily:			
Discharges	44	30	28
Outpatient Visits	44	199	360
E.R. Visits	48	0	218
Laboratory Tests	1085	4936	4341
Radiology Procedures	198	165	227
Meals Served	1743	2381	1318
Avg. No. Full Time Equivalent Staff	1033	1605	2200
Total Hospital 24 Hour Population (Inpatients, Outpatients, Staff)	1460	2204	2961
Quantity of Waste Per Unit of Full Time Population:			
Pounds	1.6	2.0	1.24
Cubic Feet	0.39	0.71	0.40
Total Gross Floor Space, Sq. Ft.	451,530	677,700	551,520
Quantity of Waste Per 100 Sq. Ft.:			
Pounds	0.50	0.65	0.67
Cubic Feet	0.12	0.23	0.22

TABLE 5

SOLID WASTE GENERATED DURING 24 HOUR PERIOD AVERAGED FOR 7 CONSECUTIVE DAYS

ITEM	ST. MARY'S HOSPITAL	V.A. HOSPITAL	MARTIN LUTHER KING HOSPITAL
Bagged Waste Transported By P/N Tube:			
Pounds	882	1115	2218
Cube	382	557	1008
Avg. No. of Bags in 24 Hours	147	316	528
Avg. Weight, Lbs/per Cubic Foot	2.3	2.0	2.2
Bagged Waste, Cartons, Boxes, Etc. Transported By Hand Cart:			
Pounds	1391	3330	1460
Cube	185	1018	180
Avg. No. of Cart Trips, 24 Hours	15	57	16
Avg. Weight, Lbs/per Cubic Foot	7.5	3.3	8.1
Total Waste Transported			
Pounds	2273	4445	3678
Cube	567	1575	1188
Avg. Weight, Lbs/per Cubic Foot	4.0	2.8	3.1

From these figures, it can be seen that, of the total waste generated in the hospitals, as much as 75 percent by weight is hand carried through the building. In general, this represents the heavy items in the total waste load and consists of crating materials, bottles, metal, heavy cartons, and other items too large to fit the chutes. The figures reveal that this material has a density per cubic foot of up to three times the waste sent down the chutes and therefore occupies as low as 30 percent of the total cube for the waste from the entire building.

TYPES OF WASTE TRANSPORTED BY HAND CART

With the installation of a pneumatic tube waste transport system, the question is raised as to why wastes would be manually transported, and what the make-up and quantities might be. In the three hospitals studied, the wastes that are carted to the central collection point covered a wider variety and larger quantity than might be expected.

SHIPPING CARTONS, WOODEN BOXES, AND CRATING MATERIAL

Virtually all cardboard outer shipping containers and boxes of 100 pound test or heavier corrugated board were found to be too large to enter the chute. These range from I.V. bottle and baby formula cartons, to shipping boxes for medical and surgical supplies, pharmaceuticals, chemicals, X-ray film, EDP paper, and general stores.

The Receiving and Warehouse Departments were the largest producers of this waste material, as might be expected. In addition, large numbers of complete cartons of supplies were sent into various support and ancillary departments (such as dietary, main kitchen, laboratory, central sterile supply, radiology, and pharmacy) and this added to the waste load from disposing of the empty cartons. Nursing stations usually received supplies broken down into smaller units and had few outer cartons. It would seem that this could be accomplished in the other departments to some degree.

Wooden boxes appear in the kitchen in smaller quantities each year, as they are replaced by corrugated cartons. Some additional wooden boxes are hand hauled by maintenance and engineering for heavy items such as plumbing supplies. Wooden crating material rarely gets on to the floors of the three hospitals studied. When heavy equipment is received in this material, it is usually broken down at the dock or in the receiving or warehouse areas.

The quantities of cardboard shipping cartons hand-hauled on a single day was substantial. At the Veterans Administration Hospital, San Diego, it amounted to 445 pieces, originating from the canteeen (68), radiology (30), laboratory (19), O.R. (4), basement areas (79), day shift for all departments (113), and night shift for all departments (132). These empty cartons weigh up to 2-1/2 pounds each. Hence, this is 1/3 of the total weight of hand hauled waste. The other two hospitals had similar percentages in their total waste.

None of the hospitals had any mechanical equipment installed in their receiving area, warehouse, or support departments that would modify such cartons and boxes so the material could be bagged and transported by the pneumatic chute. This would apply to virtually every hospital in the country. The authors of this study have for years examined various shredding, grinding, and crushing devices produced for industrial operations to see if they could be used for this purpose. To date, none have been found that are small enough, inexpensive enough, and most important, quiet operating to be practical to install in the various floor work areas of a hospital. However, if the central waste collection area, compactor, or incinerator are a considerable distance from the warehouse or receiving section, it might be economically feasible to place a chute station at this point, along with a heavy duty grinder or heavy carton shredder with a bagging attachment. It must be capable of handling all such material.

In many commercial operations, shipping cartons are cut up with hand knives to flatten them and expedite waste removal. This also was not done in the hospitals studied. Admittedly, it must be done properly. All three hospitals had experienced the phenomenon of "box accordioning" in chutes, in which a flattened box opens in transport and creates a jam. Breakdown, to be effective, must cut the carton into pieces under 14" by 14" in size.

GLASS AND METAL CONTAINERS

The use of glass containers in hospitals appears to have declined in recent years and been replaced to a degree by plastics. As an example, certain blood is now contained in plastic bags, as well as some I.V. fluids. However, glass bottles are still substantial, making up as much as 8 to 15 percent of the total waste weight in hospitals.

Two of the hospitals had experienced glass breakage in the pneumatic tube system that could possibly create glass splinters in the soiled laundry, or liquid problems if not emptied before transport. Glass containers are supposed to be dumped of all liquids before depositing in lined waste containers, but occasionally this has not been followed out by nursing and technical personnel. Both these hospitals felt that glass bottles and metal cans, even though bagged, created noise problems going through the tubes. Aerosol cans create a special problem and are not sent through the tube system for fear of explosion possibilities.

For these reasons, both hospitals place all glass bottles and metal containers in separate and labeled waste receptacles with distinctive bag liners in each soiled utility room or support department and cart-haul the bagged glass and metal daily to the central collection point.

The third hospital, using heavier wall tubing, as well as separate trash and linen tubes, has experienced no problem with glass and metal in the systems, including aerosol cans.

OVERSIZED BAG LOADS

It was discovered that certain areas, such as O.R., canteen, warehouse, and Central Sterile Supply, are heavy waste generators and use a certain number of waste containers, such as 30 gallon plastic garbage cans, with plastic bag liners too large to send down the pneumatic chutes. Except for the cube of the load, there was nothing in the material that would create problems in the system. However, this resulted in these over-sized bags of waste being cart-hauled. Recommendations were made to install smaller containers, or adaptors for the regular sized chute bags in the large containers, and send this material through the pneumatic system.

INFECTIOUS OR CONTAMINATED WASTE

The survey found the operational thinking to be entirely different between the hospitals on the subject of handling infectious or contaminated material. At Martin Luther King Hospital, with a completely closed system and heavy wall tubing, it was felt that all infectious and contaminated material should go through the pneumatic system as offering the least possibility for cross contamination and the spread of aerosols creating infection problems in the house.

At the Veterans Administration Hospital, all such material, along with the material from surgery, is not sent through the system but rather is bagged in red plastic and hand carted to the incinerator room. At this institution, each surgery has a kick bucket with a special non-static liner. Waste generated is placed in these and then double bagged in a red plastic outer bag. It is then transported in special aluminum carts that are sanitized after each trip. The V.A. is a heavy user of disposable surgical drapes which adds considerably to this load. The hospital has experienced considerable bag ripping in the tubes, and is fearful of contaminating the soiled laundry with contaminated or infectious waste.

At St. Mary's Hospital, infectious and contaminated solid waste is sent through the system, as their double bagging system has apparently prevented bag breakage.

The only hospital with research animal quarters was the Veterans Administration. All bedding generated in cage cleaning is regarded as contaminated and is red bagged and transported by cart.

Other surveys in hospitals have stated that the material that can be definitely established as infectious and contaminated is only in the neighborhood of 4 percent of the total solid waste load.[3] In this present study, the researchers found that this figure is low by at least 50 percent. The percentage clearly established by the V.A. San Diego Hospital as infectious was almost exactly in line with the other two hospitals in this present study. It represents 10.7 percent of the 3330 pounds of *cart* transported material at San Diego. Eight percent of the *total* waste transported by cart and tube generated in each of the three hospitals was clearly established as potentially infectious.

HYPODERMIC NEEDLES AND SHARPS

Probably the most dangerous item in a hospital as a potential cause of spread of infections is a hypodermic needle. With the introduction of disposable needles plus the increase in injections in the past 15 years, the number of needles generated as waste has increased at least twenty times. With the increase in drug addiction in the United States, hospitals have also become sensitive to the use of their needles by drug users, particularly after use in the hospital. Hence, most institutions break needles after use. The theory is fine. The equipment to accomplish it, on the nursing floors, is not. Most nursing station needle breakers are flimsy, and a source of nursing irritation. The disposable "catch containers" are not satisfactory.

Many examples were given the survey team of broken needles and/or sharps projecting through the bags and puncturing the hands of waste handlers. It would seem that all such items could be deposited in the waste in inexpensive metal cans, such as a taped soft drink can, so that there is no possibility of injury to waste handlers.

PATHOLOGICAL WASTE

The quantity is quite small, but as most state laws enforce destruction in pathological incinerators, it is hand carried, normally red bagged, from operating rooms, autopsy suite, and animal quarters, and disposed of by burning.

RADIOACTIVE WASTE

This is subject to special regulations originally promulgated by the Atomic Energy Commission and is disposed of in special containers to special sites. In a hospital, the total quantity is small.

AREAS AND HOURS NOT SERVICED BY THE CHUTE SYSTEM

In two of the hospitals, it was determined that at certain time periods, general waste should be hauled by cart instead of sent through the chute system. This thinking has been revealed in several other hospitals studied by the survey team. The reasoning is that the system should be shut down during the late evening hours (for example, from 10:30 P.M. to 6:00 A.M.) in order to ensure better control over the chute loading. To reduce floor waste to a minimum, at least one "sweep" is made of the building during this period, particularly in public lobbies and in the 24-hour Emergency Department. At the Martin Luther King Hospital, this is not the case and the chutes are available 24 hours a day.

Certain areas are not served economically by the chute system due to design, or architectural omissions or weaknesses. For example, time studies in the V.A. Hospital revealed that, for the first floor office areas, at the end of the business day less labor is required in collecting the waste if a cart hauling system is used, emptying all waste baskets in one sweep and taking an entire cart load directly to the compactor.

It has also been pointed out that this applies to dock and receiving area waste when it is found that, even though small enough to fit the chute system, due to the close proximity of the compactor less labor is used if it is carted directly to the collection room rather than to a chute station that would be further away.

DENSITY OF HAND CARTED WASTE

The table on page 119 reveals that the hand-carted waste is much heavier per cubic foot (denser) than the waste transported in the pneumatic system. This would be expected, as the hand-carted waste consists of corrugated cardboard and crating lumber, glass bottles, engineering supplies, maintenance materials and metal, in as much as 60 percent of its total; whereas the bagged waste transported by chute is over 90 percent paper, light cardboard, plastic, and cloth.

GENERATION POINTS AND QUANTITIES OF WASTE TRANSPORTED BY CARTS

There is not the consistency of quantity in transporting the type of waste handled by cart as there is in sending bagged waste in the pneumatic tube system. This arises from the fact that the bagged waste has a direct relationship to the number of people in the total population of the building. The total waste handled by cart is more dependent on the activities of the ancillary and support departments and particularly, the delivery of supplies to the hospital and its departments due to the effect of the quantity of shipping containers in the total load.

As the Veterans Administration Hospital had the largest census, the most complex ancillary and support procedures, and the heaviest waste load transported by cart, it reveals these points most clearly among the three hospitals. Further, the statistics are comparable with other hospitals that use the cart movement method for solid waste management. The following breakdown of hand-carted waste in a typical week shows its make-up and the departments that produce it.

DIETARY

The quantities transported per day were fairly consistent. They averaged 124 pounds in the morning; 166 pounds in the afternoon; and 125 pounds in the evening. The bulk of this was shipping cartons, followed by tin cans, some bottles, and a few wooden boxes.

ENGINEERING

Variations from day to day were extremely heavy. The work period was a five day week. Variations arose from the assignment of work schedules.

DAY	POUNDS
Monday	250
Tuesday	35
Wednesday	50
Thursday	140
Friday	300

WAREHOUSE

The waste consisted entirely of heavy cartons and wooden boxes and differed considerably from day to day over the five day work period:

DAY	NO. CARTONS	NO. WOOD BOXES	TOTAL WEIGHT LBS.
Monday	184	0	423
Tuesday	89	140	1048
Wednesday	144	30	554
Thursday	214	50	814
Friday	171	0	393

The day to day variations arise from variations in receipts, as well as issues, to the floors.

SURGERY

The waste load would be expected to tie into the operating room procedure schedule, and this can be seen from the following breakdown by weight over the five day work period:

DAY	CONTAMINATED	GLASS & GENERAL	CARTONS	TOTAL WEIGHT LBS.
Monday	12	220	10	242
Tuesday	8	268	10	286
Wednesday	12	200	10	222
Thursday	4	168	10	182
Friday	8	112	3	123

LABORATORY

This department does both clinical and research work. As can be seen from the figures, it peaks toward the middle of the week and generates waste over a seven day work period, with a weight breakdown by type as follows:

DAY	CONTAMINATED	GLASS & METAL	GENERAL	CARTONS	TOTAL WEIGHT LBS.
Monday	16	36	96	50	198
Tuesday	4	120	180	18	322
Wednesday	28	90	186	21	325
Thursday	44	90	30	38	202
Friday	36	72	40	18	166
Saturday	12	72	88	28	200
Sunday	--	--	--	21	21

RADIOLOGY

Compared to other ancillary departments, this is not a heavy producer of solid waste, and the weight load is fairly level over the five day work period:

DAY	CONTAMINATED	GLASS & METAL	GENERAL	CARTONS	TOTAL WEIGHT LBS.
Monday	0	88	48	44	180
Tuesday	0	72	48	8	128
Wednesday	0	94	40	28	162
Thursday	0	88	40	14	142
Friday	3	64	48	6	121

CANTEEN

Indicating a fairly consistent level of activities, the weights of waste generated during the week days are similar from day to day, with a week-end decline:

DAY	GLASS & METAL	GENERAL	CARTONS	TOTAL WEIGHT LBS.
Monday	60	103	94	257
Tuesday	192	42	74	308
Wednesday	336	24	22	382
Thursday	288	26	68	382
Friday	328	38	15	381
Saturday	0	112	0	112
Sunday	24	64	74	162

With the exception of the warehouse, which generated an average of almost 650 pounds per day, and the canteen at over 280 pounds, the other support departments were quite similar in load, with daily averages ranging from 150 to slightly over 200 pounds. The above departments added together represent just under 50 percent of the solid waste transported by cart. The remaining solid wastes, moved by hand carts, come mainly from the outpatient clinics, central sterile supply, nursing stations, laundry cartons, inhalation and physical therapy, and various offices, as recapitulated in the following figures of pounds produced each 24 hour period, and the breakdown by type:

DAY	CONTAMINATED	GLASS & METAL & NON-COMBUSTIBLE	GENERAL	CARTONS	TOTAL WEIGHT LBS.
Monday	233	608	452	174	1,467
Tuesday	398	860	328	594	2,180
Wednesday	435	710	476	286	1,907
Thursday	341	820	286	810	2,257
Friday	482	596	308	386	1,772
Saturday	175	520	206	174	1,075
Sunday	164	640	223	130	1,157
TOTAL LBS PER WEEK	2,228	4,754	2,279	2,554	11,815
DAILY AVERAGE LBS	318	679	326	365	1,688

COMPARISONS OF SYSTEM UTILIZATION
CART-HAULING VERSUS PNEUMATIC TRANSPORT

Each of the three hospitals has a slightly different philosophy on solid waste management. This involves the total hours of the day active removal and transport shall take place; the hours during which the pneumatic system will operate; how the waste shall be initially collected from each room and how it shall be removed from the floor; the use of specialized personnel to cart-haul or load chutes versus random removal or loading by general housekeeping maids and nursing aides; the items and type of waste that will be deposited in the chutes versus being hauled from the floors by cart. All are supervisor edicts.

These differences in management philosophies have a marked effect on the utilization of the pneumatic transport system in each hospital. The percentage of total waste transported by pneumatic tube, as against the percentage hauled by cart, differed substantially in each hospital. The differences are far greater than would be expected and result almost entirely from management decisions as to the amount and type of waste that will be permitted to be transported by chute. In each institution the chute wastes are of lighter weight and greater cube per pound than the cart transported wastes. This explains the higher percentages in cubic volume as against weight that are transported by tube.

When the weights of waste are compared between the hospitals we have seen, for example, that the Veterans Administration generates a total weight of 63 percent more waste per inpatient than St. Mary's and 40 percent more total weight for its 24-hour population than St. Mary's. When this is analyzed still further, almost the entire difference arises from the extreme weight at the Veterans Administration Hospital in the items that must be transported by cart rather than sent through the pneumatic system.

Partly this has to do with the hours during which the pneumatic system is in operation. The details of this are shown later in this chapter. Partly it has to do with the supply practices in each hospital and the amount of heavy waste or large bulky waste that is permitted to go onto the floors of the building and cannot be transported, due to size, by the pneumatic tubes.

And partly it concerns decisions that certain items will, for one reason or another, not be sent in the pneumatic system for fear of breakage, bag tearing or other reasons.

In surveying other hospitals that have pneumatic systems, it would be safe to state that almost all full vacuum systems that have been installed for transporting waste to date are under-utilized and that too much material is going around the systems by expensive hand carting methods.

The figures in Table 6 give the comparisons between the three hospitals, showing the percentage of material by weight and by cubic foot that is transported in the pneumatic system as against being transported by hand cart.

TABLE 6

COMPARISONS AND UTILIZATION OF TUBE AND CARTS

	ST. MARY'S HOSPITAL	V.A. HOSPITAL	MARTIN LUTHER KING HOSPITAL
Avg 24 Hour Weight Transported by Pneumatic Tube	882	1,115	2,218
Avg 24 Hour Weight Moved by Cart	1,391	3,330	1,460
Total Weight in Pounds	2,273	4,445	3,678
% of Total Weight Transported by Tube	38.8%	25.1%	60.3%
Avg 24 Hour Cube Transported by Pneumatic Tube	382	557	1,008
Avg 24 Hour Cube Moved by Cart	185	1,018	180
Total Cubic Feet	567	1,575	1,188
% of Total Cube Transported by Tube	67.4%	35.4%	84.9%

As seen in the chapter on economics, hand carted waste is expensive material to transport, requiring as much as 21 manhours per day to clear it from the floors and move it to the central collection point, for the hospitals in the present study.

QUANTITIES OF WASTE TRANSPORTED BY PNEUMATIC TUBE

Seven consecutive 24-hour surveys were conducted at each of the hospitals to analyze the waste transported by the pneumatic system and to determine:

- Where the waste originated
- Of what it was comprised
- In what chute station it was discharged
- At what time of day it was discharged
- What were the weights and cubes transported, by type of waste, time of day, and chute station
- What were the weights and cubes of the individual loaded bags

The surveys were conducted at all chute loading doors in the house simultaneously, with every bag recorded at every door before deposit into the chutes.

THE SIZING OF UNIT LOADS

The comparisons between the three hospitals of quantities of waste transported by pneumatic tube must take into consideration the size of the tube and hence the size of the transport bag used.

Martin Luther King Hospital uses a gravity to vacuum system with a 20" tube. This permits the use of a bag as large as 29-1/2" wide by 35" long in the flat; which could produce a fully loaded bag 19" diameter by 25" long, holding 4.1 cubic feet of waste.

Both the Veterans Administration Hospital, San Diego, and St. Mary's Hospital, Duluth, use 16" diameter tubes; permitting the use of bags 23-1/2" wide by 33" long in the flat, giving a fully loaded bag 15" diameter by 25" long, holding 2.3 cubic feet.

In view of the cost of transport bags and the waiting times involved in a full vacuum system, there is a need to load bags as full as practical with regard to bulk or volume. Weight will obviously vary, depending on the nature of trash and its compaction in the bag. Surveys reveal that "fully loaded" 15" by 25" bags will vary in total weight, from 3.5 pounds to over 13 pounds, with the normal filling practices of housekeeping workers. The "average" weight of this size bag should be 6.0 to 7.2 pounds when loaded with hospital chute trash, depending upon whether glass bottles and metal have been included. The larger bags used in the gravity to vacuum system will average 10.7 pounds fully loaded, and up to 12.0 pounds average if all glass and metal is deposited in the chutes.

A three mil thick plastic trash bag will easily support these weights of waste in the cubes that are listed above. Further, it was discovered at St. Mary's that such bags have a considerable amount of stretch and could be considerably overloaded as to cube and still go through the system without tearing or without plugging the system, as they "elongate" during transport. Measurements of a representative succession of bags showed the following diameters and lengths:

16"x29"
17"x24"
16"x25"
17"x29"
14"x29"
14"x22"
16"x24"
21"x26"
19"x28"
15"x27"
20"x27"
18"x29"
16"x29"
15"x27"
21"x25"
16"x25"
13"x26"
17"x27"
21"x29"
19"x30"
16"x26"
18"x24"
15"x24"
21"x28"
17"x26"
15"x27"
19"x27"
19"x26"
18"x25"
16"x23"
17"x23"

DAILY QUANTITIES TRANSPORTED

The figures reveal an important fact about pneumatic tube transport systems. Hospitals that have installed 16" diameter tubes show considerable differences in the average cube and weight of the bags of waste that are transported, while at the same time the density of the waste only varies from 10 percent to 15 percent between such hospitals. This is evident in studying the figures from the Veterans Administration Hospital and St. Mary's, with a difference of 44 percent in cube and 70 percent in weight for the average bag load between these hospitals and only 13 percent in waste density.

The main reason in all hospitals studied appears to arise from experiences with plugging and bag breakage when the tube system first starts in operation. Each hospital experiments with the bagging methods used to avoid this. One hospital will reduce the loading of individual bags to ensure they are kept rather small. Another, such as St. Mary's, will lean toward double bagging in extremely strong bags, even to the point of adding nylon mesh reusable bags over these. As a result, the loading of individual bags is increased as the hospital finds the bags are standing up to transport.

Surveying the total number of waste bags placed in the pneumatic system in the seven consecutive days that were studied, we find the following:

TABLE 7

DAILY QUANTITIES OF WASTE TRANSPORTED IN PNEUMATIC SYSTEM

	ST. MARY'S HOSPITAL		V.A. HOSPITAL		MARTIN LUTHER KING HOSPITAL	
DAY OF WEEK	BAGS	LBS.	BAGS	LBS.	BAGS	LBS.
Monday	148	902	170	612	562	2360
Tuesday	155	942	416	1513	522	2192
Wednesday	165	973	342	1165	668	2806
Thursday	146	949	571	2070	521	2188
Friday	154	919	186	651	662	2780
Saturday	138	801	329	1119	281	1180
Sunday	123	689	206	679	482	2024
Weekly Total	1029	6175	2210	7809	3698	15,530
Daily Average	147	882	316	1115	528	2218
Daily Average Cube	382 cu ft		557 cu ft		1008 cu ft	
Average Bag Weight	6.00 lbs		3.53 lbs		4.20 lbs	
Average Bag Cube	2.6 cu ft		1.8 cu ft		1.9 cu ft	
Average Weight of Waste Transported	2.3 lbs/cu ft		2.0 lbs/cu ft		2.2 lbs/cu ft	

FLOOR COMPACTORS

The survey team did an investigation on the use of household compactors in the three hospitals and found that none were in use. The theory of installing these units by each chute station is that they are inexpensive and will pay for themselves in under four years by increasing the density and reducing the bulk volume of waste sent through the system. With the waste generated in the nursing floors and support departments, it has been discovered that one of these units gives an average compaction rate of approximately 4 to 1. Presumably this would reduce the number of bags by 4 to 1 and reduce chute loading waiting time. It would also increase the weight of each bag by at least four times and would provide more uniform bag loading.

Not enough hospitals have installed these small home compactors to date to prove their economic feasibility. However, it is known that, as the cost of bags used in these is approximately four times the cost of chute bags, no savings would be obtained in this aspect. Further, they represent one more step in the process and would add extra labor for lining the chamber with the compactor bag. As against this, chute loading total time would be reduced 75 percent in a full vacuum system and a much tougher transport bag would be used. With the exception of large cartons and boxes, cart hauled waste could also be reduced by 75 percent in bulk.

It would appear worthwhile to study the pros and cons of these units.

CHUTE LOADING HOURS AND VOLUMES

When the figures for waste bags alone are studied, the hourly quantities placed in individual stations are not particularly large. However, with the full vacuum systems of St. Mary's and the Veterans Administration, the stations must be examined for the ability to handle trash and linen at virtually the same time, and the totals of both within a given hour must be recorded to show the volume ability of the system.

At first glance it would appear that a full vacuum system, capable of receiving only one bag at a time,is quite limited in volume capacity. St. Mary's, with separate waste and linen tubes, was able to put through the system in the morning peak single hour between 110 and 120 bags maximum, of waste and linen combined.

The Veterans Administration, using a multiple loading and single tube,-full-vacuum system, and with a specialized operator doing the chute loading for the entire hospital, was able to send as high as 232 combined laundry and waste bags through in a single morning peak hour; or over twice what the limits of the single bag transport system set, despite the use of a single tube.

The housekeeping management practices do enter into this loading speed. It will be seen that St. Mary's loads waste and linen bags into the system at a relatively even rate from early morning until late evening, over a 17 hour period. The Veterans Administration, on the other hand, does the majority of the station loading in 4 to 6 very high peak hours per day, in the mid-morning and early afternoon.

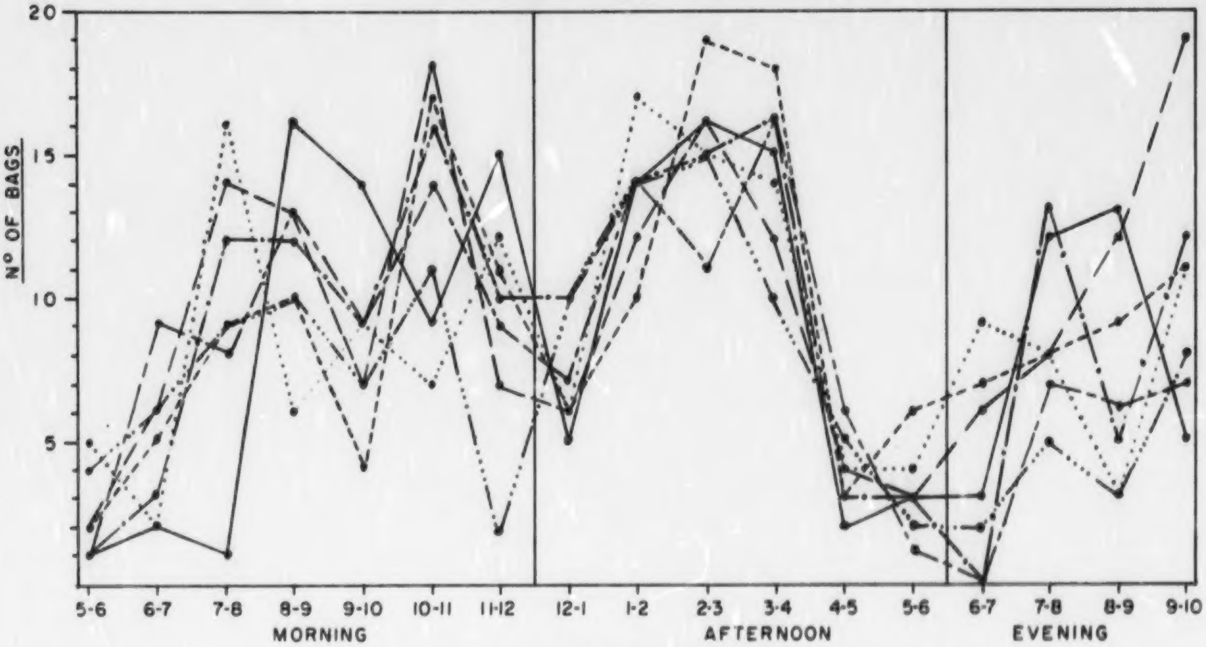
These patterns are created by the management system used in each hospital. St. Mary's uses random loading, in which all maids and porters from housekeeping that clear the rooms and hospital support departments, and all nursing aides that handle the laundry on the various floors, also deposit bags in each of the chutes as they generate them. At the Veterans Administration, the housekeeping and nursing aide personnel merely clear the areas, tie the bags, and take them to the chute rooms for temporary storage. One operator then goes from floor to floor, four to six times per day, and puts the bags down the chutes on a multiple loading basis. Further, at the Veterans Administration Hospital, the clearing period from patient rooms and support activities is over a much shorter time period, and without the late afternoon and early evening hours found in a community hospital handling private patients.

Figures 11 through 16 show the loading of each chute station in each hospital over each hour of the day that the pneumatic transport system is in operation. These surveys, over seven consecutive days, reveal clearly the loading patterns used in each hospital. They also show the management practices on the part of housekeeping, maids, and aides in clearing the floors; and they reveal the ability of each system to handle a given volume per hour from individual stations.

ST. MARY'S HOSPITAL.

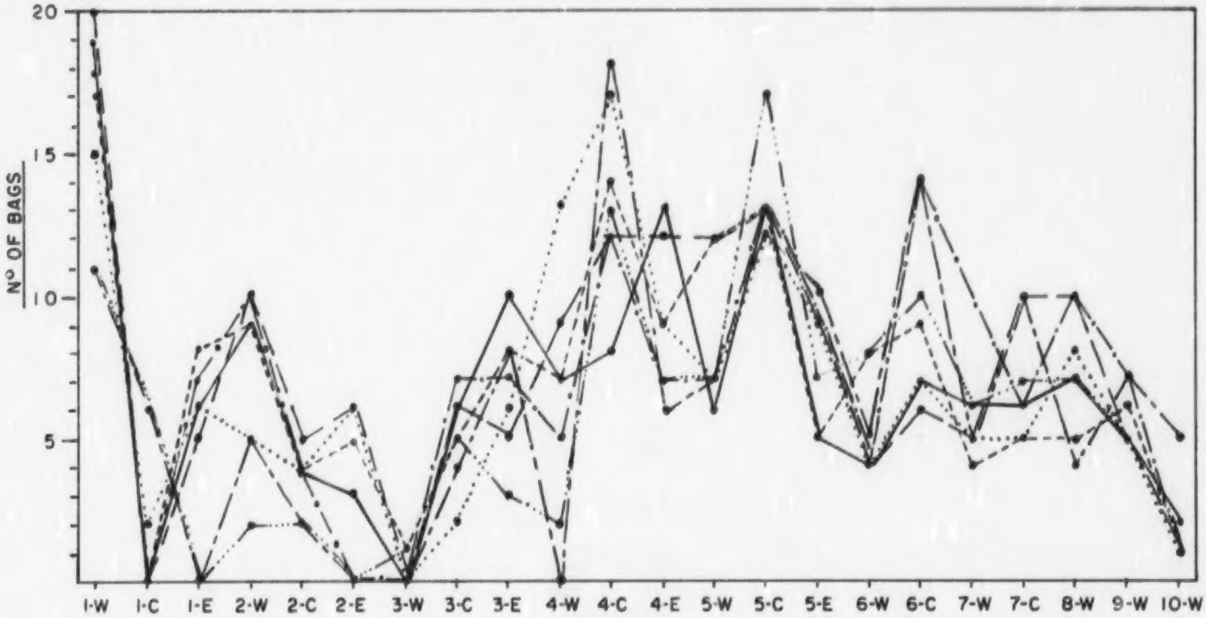
SEVEN DAY CHUTE LOADING

FIGURE 11.



LOADING BY TIME OF DAY

FIGURE 12.



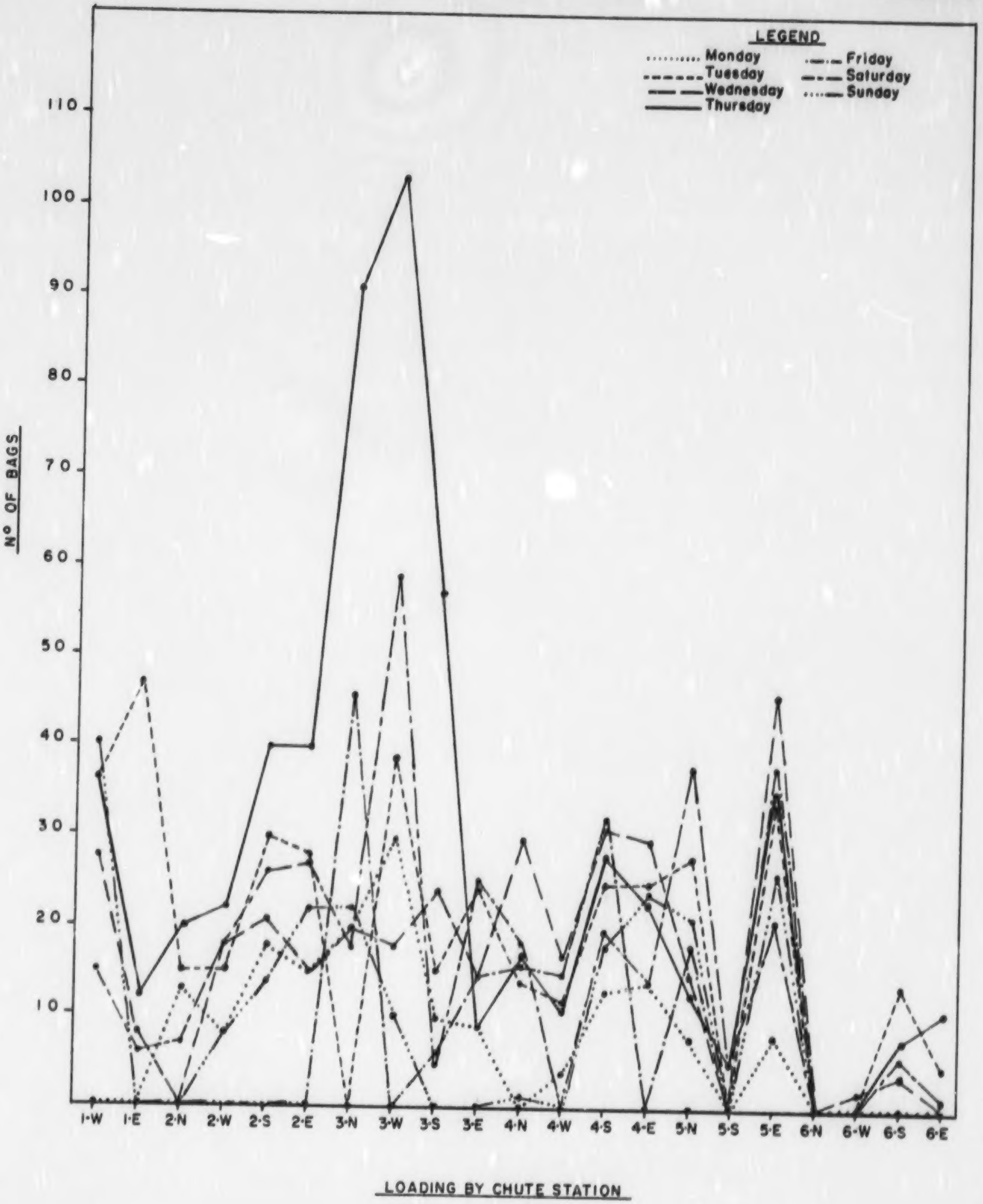
LOADING BY CHUTE STATION

LEGEND
...... Monday
---- Tuesday
— — Wednesday
—— Thursday
.—.— Friday
—-—- Saturday
....— Sunday

VETERANS ADMINISTRATION HOSPITAL

SEVEN DAY CHUTE LOADING

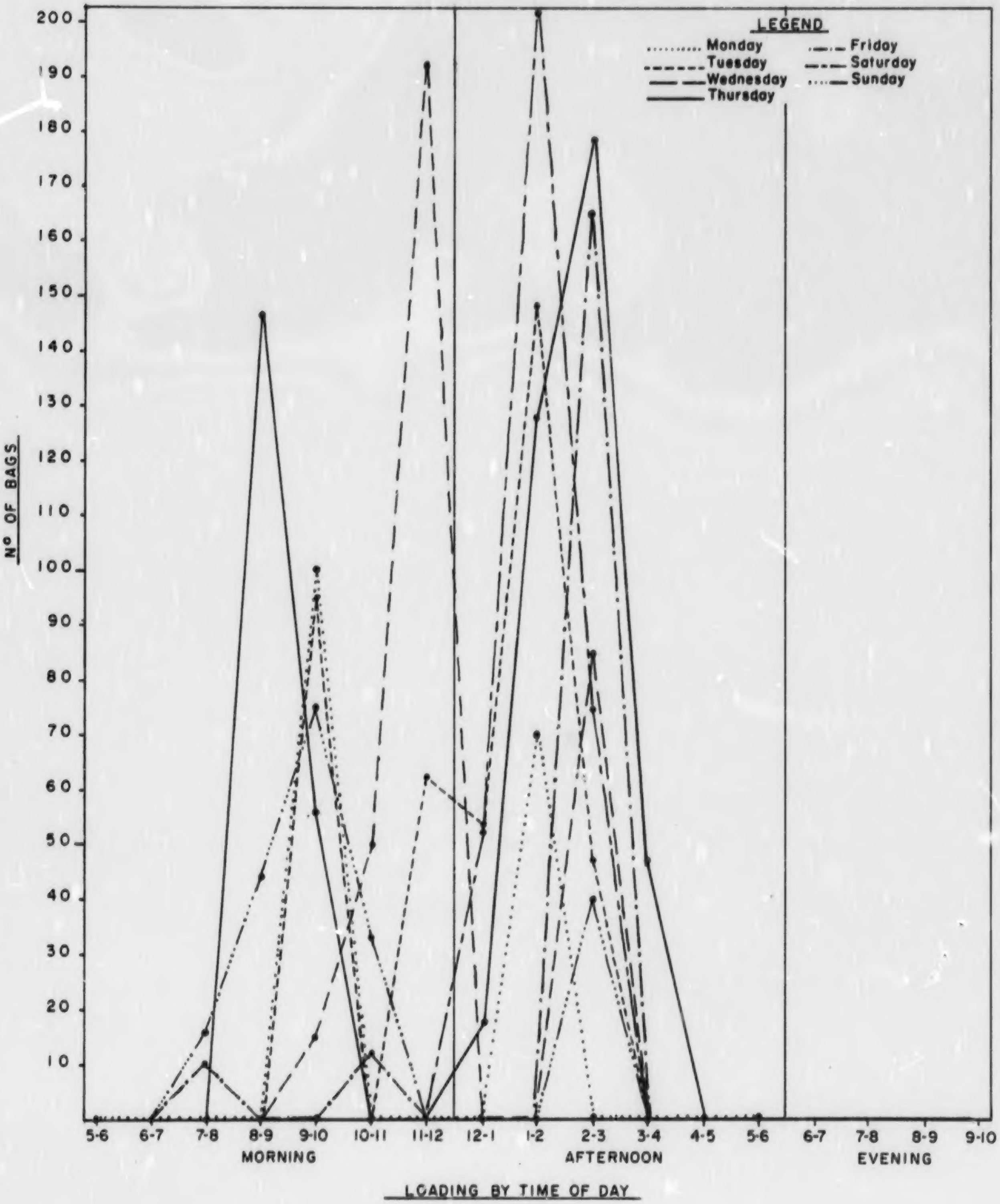
FIGURE 13



VETERANS ADMINISTRATION HOSPITAL

SEVEN DAY CHUTE LOADING

FIGURE 14

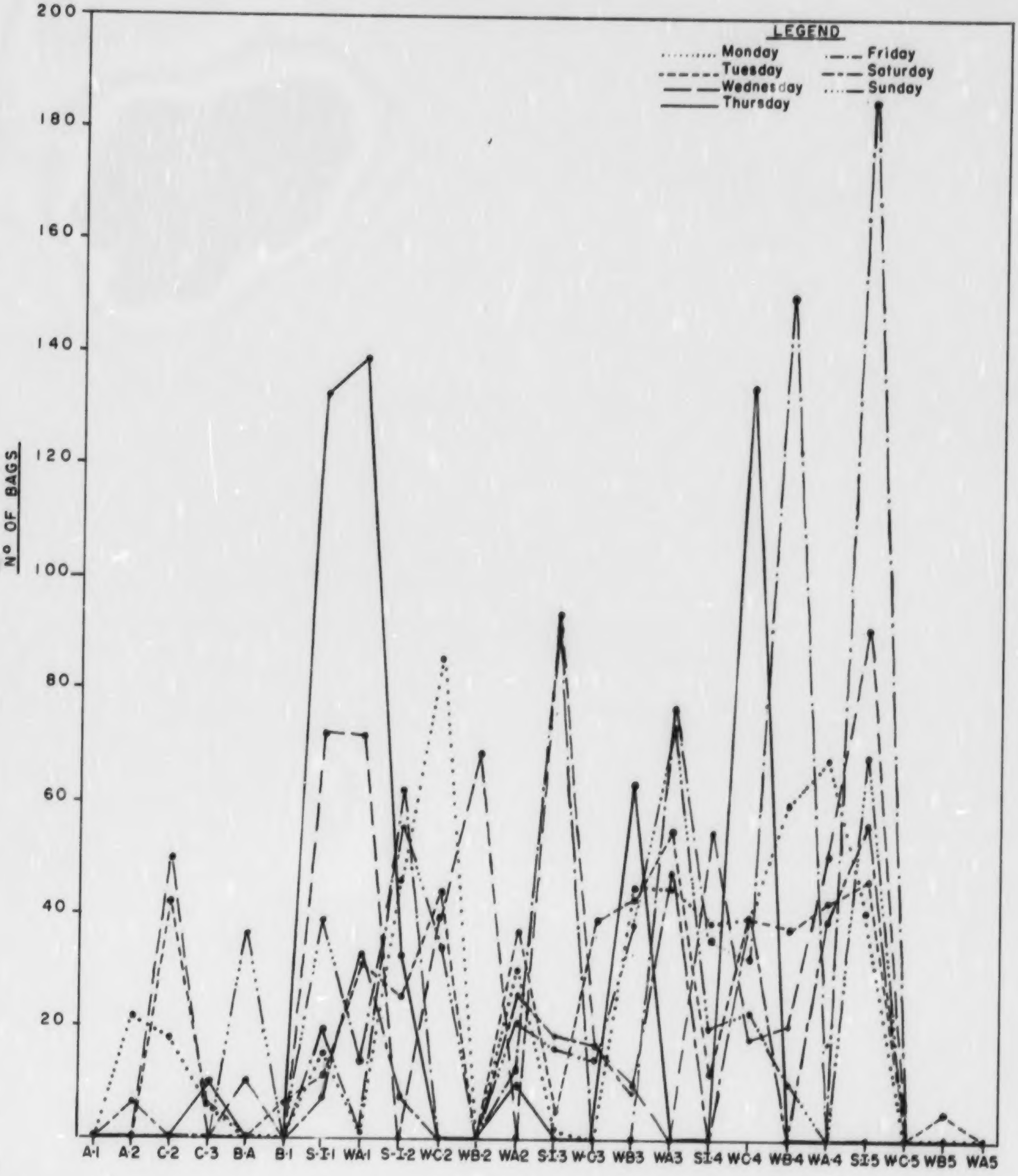


LOADING BY TIME OF DAY

MARTIN LUTHER KING HOSPITAL

SEVEN DAY CHUTE LOADING

FIGURE 15

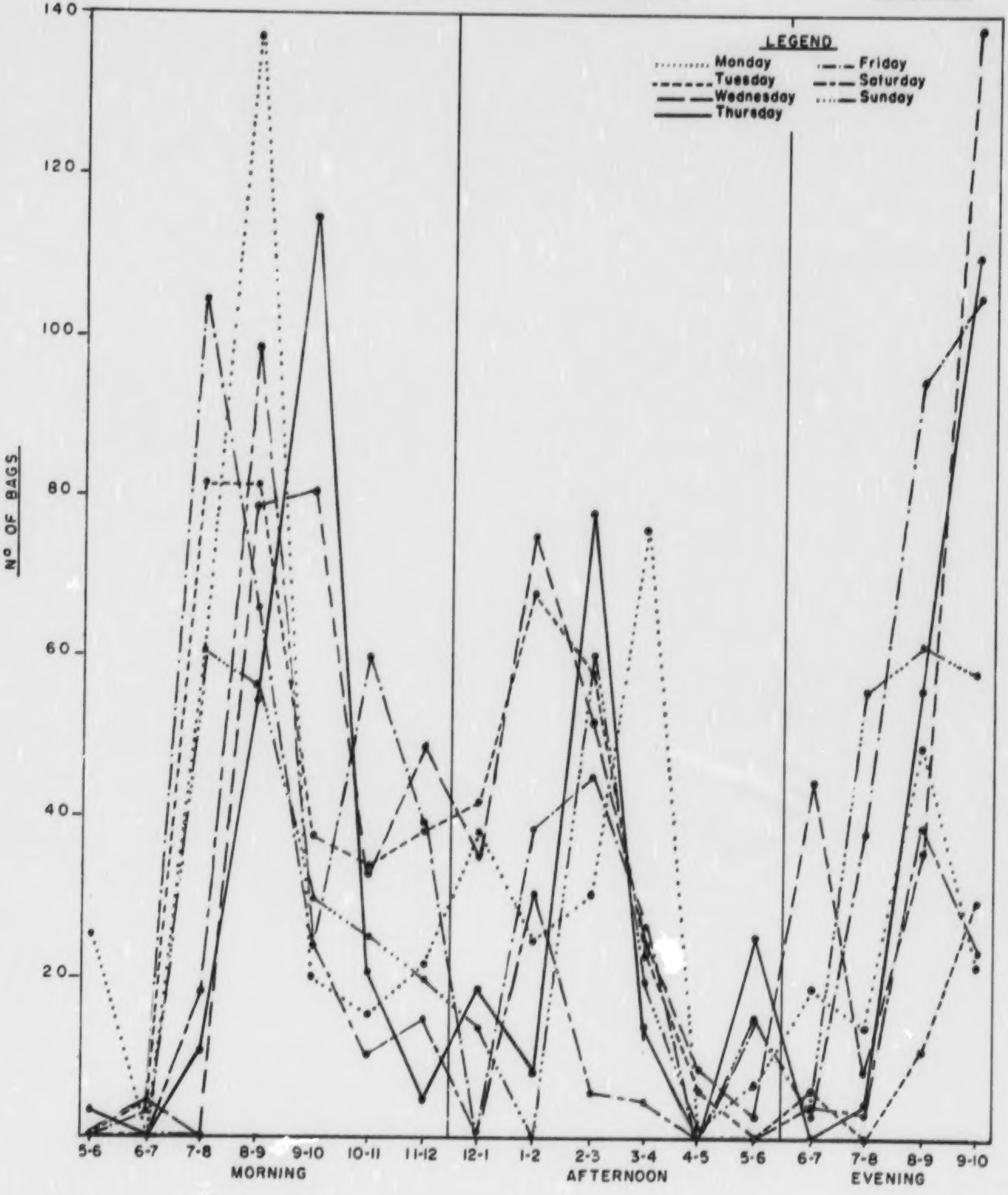


LOADING BY CHUTE STATION

MARTIN LUTHER KING HOSPITAL

SEVEN DAY CHUTE LOADING

FIGURE 16



LOADING BY TIME OF DAY

THE INTERFACING OF SOILED LAUNDRY AND WASTE IN THE PNEUMATIC SYSTEM

No hospital has installed a pneumatic tube transport system for waste alone. In each case soiled laundry is moved along with the waste, either in the same tube, or in separate tubes, usually with a common fan. Studies of the loading figures in hospitals such as St. Mary's and the Veterans Administration always reveal that the quantities of laundry transported in the system exceed the waste, in cube, in pounds, and in number of bags sent per hour. Further, the movement of laundry always takes precedence over the movement of waste, Only when two entirely separate systems are installed (as in the case of Martin Luther King) can waste removal be completely independent of laundry.

In St. Mary's and the Veterans Administration, using the full vacuum system dependent on a single fan and, in the case of the V.A., restricted to a single tube, the waste management is highly influenced by the removal of laundry. When laundry must be transported, the system is not available for waste transport. The figures in Table 8 show how important this influence can be.

TABLE 8

DAILY QUANTITIES OF WASTE AND LAUNDRY TRANSPORTED BY PNEUMATIC SYSTEM

NUMBER OF BAGS

	ST. MARY'S HOSPITAL			V.A. HOSPITAL			MARTIN LUTHER KING HOSPITAL		
Day of Week	Waste	Laundry	Total	Waste	Laundry	Total	Waste	Laundry	Total
Monday	148	695	843	406	336	742	562	344	906
Tuesday	155	685	840	342	414	756	522	337	859
Wednesday	165	648	813	571	506	1077	668	726	1394
Thursday	146	604	750	186	323	509	521	354	875
Friday	154	561	715	329	368	697	662	532	1194
Saturday	138	448	586	206	261	467	281	213	494
Sunday	123	438	561	170	395	565	482	406	888
Totals	1029	4079	5108	2210	2603	4813	3698	2912	6610
Daily Average	147	583	730	316	372	688	528	416	944
Percent of Total	20%	80%		46%	54%		56%	44%	
Avg.per Operating Hour	8	34	42	80	80	96	29	23	52

WASTE GENERATION POINTS AND VOLUMES

From what has been described in the preceding sections, we have seen that it is virtually impossible to plan a pneumatic transport system and locate the stations throughout the hospital so that they are loaded equally. Some departments and nursing floors and wings generate much more waste than others. The science in designing the layout of such a system is to attempt to place the stations so that the load is somewhat equalized and that each and every station can be proven to be worth the expenditure involved in installing it.

Table 9 gives an indication of the equality or inequality of loading of the individual stations with a combination of waste and laundry bags in each hospital.

TABLE 9

UTILIZATION OF CHUTE LOADING STATIONS

Hospital	Total No. of Stations	No. of Stations Used for Sending	
		50% of Bags	80% of Bags
St. Mary's	Waste--22	8	13
	Laundry--19	5	9
Veterans Administration	Waste--27	6	11
	Laundry--27	5	9
Martin Luther King	Waste--24	6	11
	Laundry--19	6	10

The pneumatic system was laid out quite differently by the designer in each of the three hospitals with regard to the departments and stations that are to be serviced by a given chute station. Hence, direct comparisons are difficult to make between the hospitals as to the efficiency of the location of the individual stations, particularly with regard to the ancillary and support departments. This is heightened by the different concepts in each of the three institutions concerning what should be hand-carted, versus what should be transported by the pneumatic system.

Examined individually, the three hospitals show the following loading patterns in a seven day week for each station, rated in descending order of the volume of waste bags each station handles.

ST. MARY'S

STATION	NO. OF BAGS
Dietary	111
Intensive Care, P.A.R., Floor Dietary, Nursing	94
O.B., GYN., Nursery, Floor Dietary, Nursing	93
C.C.U., Nursing, Floor Dietary	67
Med-Surg Nursing	63
Obstetrics	58
Med-Surg Nursing	54
Floor Dietary, Nursing	51
E.R., X-ray	50
Floor Dietary, Formula Room, Nursing	49
Med-Surg Nursing	46
Surgery	43
Med-Surg Nursing	40
Med-Surg Nursing	37
Med-Surg Nursing	37
Floor Dietary, Nursing	35
Offices	32
E.R., X-ray	25
Offices	20
Central Sterile Supply	17
Main Lobby	10
Laboratory	2

VETERANS ADMINISTRATION

STATION	NO. OF BAGS
Nursing	259
Nursing	208
Nursing	207
Nursing	167
Outpatient Clinics	155
Nursing	149
Nursing	147
Nursing	141
Nursing	130
Intensive Care, Nursing	117
Nursing	97
Nursing	96
Nursing	89
Offices	73
Med. Illus., Cardio-Pulmonary	59
Nursing	55
Animal Research O.R. and Lab	32
Animal Research Lab	17
Nursing	10
Animal Research Lab	2
Animal Quarters	0
Surgery N	0
Surgery S	0
Central Sterile Supply	0

MARTIN LUTHER KING

STATION	NO. OF BAGS
Pediatrics, Segment I, 5th Floor	485
Nursing, Wing C, 4th Floor	328
Nursing, Wing A, 3rd Floor	296
Orthopedics, X-Ray, Segment I, 1st Floor	295
Offices, Wing A, 1st Floor	290
Nursing, Wing B, 4th Floor	279
Obstetrics, Segment I, 2nd Floor	230
O.R. & Labs, Segment I, 3rd Floor	227
Nursing, Wing B, 3rd Floor	208
Nursing, Wing C, 2nd Floor	205
Nursing, Wing A, 4th Floor	178
Clinics, Segment I, 4th Floor	161
Nursing, Wing A, 2nd Floor	139
Trash Room, C-2	118
Nursing, Wing C, 3rd Floor	89
Nursing, Wing B, 2nd Floor	69
Autopsy, Offices, Basement A	45
Kitchen, A-2	27
Central Sterile Supply, C-3	20
Kitchen, Offices, B-1	5
Nursing, Wing B, 5th Floor	4
Not Used, Wing C, 5th Floor	0
Not Used, Wing A, 5th Floor	0
Laundry, A-1	0

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1 Ross Hofmann, Associates, Solid Waste Surveys of 43 Hospitals, 1970-1971, unpublished.

2 Ibid.

3 Brewer, J. B., A Case History, in Proceedings, A.H.A. Institute on Hospital Solid Waste Management, Chicago, May 18-20, 1972.

7-OPERATIONAL AND PERFORMANCE ANALYSIS

To analyze the operation and performance of a pneumatic transport system the most revealing documents are the daily maintenance reports made by the hospital engineering staff. All three hospitals in this study keep excellent maintenance records and these were made available to the survey team covering the period from the first day of operation through November, 1973. In the case of Martin Luther King, this period was 23 months; 20 months for Veterans Administration; and 47 months for St. Mary's.

These records recorded every malfunction in each system, whether from mechanical failure or from misuse by operating personnel.

Of the three systems studied, the one at Martin Luther King General Hospital had the highest installed cost at $425,000. It also had the largest total length of tubing, with over 1,400 ft for waste alone. Comparable figures for the other two hospitals were $350,000 system installed cost at Veterans Administration Hospital, with a total of 1,894 ft of tubing used for both laundry and waste; and $193,000 system installed cost at St. Mary's, with a total of 1,700 ft of tubing for waste and linen combined.

The Martin Luther King installation has 20 in. diameter tubes of 3/16 in. wall thickness in the horizontal tubes and a combination of 14 and 10 gauge metal in the vertical chutes. It is a gravity to vacuum system. The other two systems both use smaller diameter tubes of lighter metal--16 in. diameter and 20 gauge metal--and are full pneumatic systems with loading hoppers.

The maintenance practices of the three hospitals differ slightly, and comparisons in maintenance hours used per year must be made very carefully to ensure that the hospitals, and therefore their systems, are being compared on an identical basis.

In analyzing the maintenance of any system, if detailed records are kept by the engineering department, it will be seen that maintenance hours are recorded under three different classifications. The first involves corrective maintenance, and from the point of view of determining the efficiency of any system and analyzing its operation and performance, it is the "corrective" hours that must be expended that reveal most clearly the problems involved with the system. Any efficient engineering department carries on a preventive maintenance program, which is used on a constant daily, weekly, or monthly basis to catch trouble before it occurs and prevent breakdowns in any of the operating parts of the system. In two of the hospitals (Martin Luther King and the Veterans Administration) a considerable number of maintenance hours are being used each year under a classification that is not "corrective" maintenance and is something less than "preventive" maintenance. We have termed this "routine" inspection of the system by the maintenance department. This comes about because a full man, or part of a man, is assigned full time to the system, to be on call during normal working hours to handle any problems that arise with the system. He is not assigned any other duties for these particular hours and, therefore, his time can only be charged against maintaining the system. Presumably, he is not sitting in an office during these hours but, instead, is out walking the hospital and determining, on a constant basis, that the system is operating properly.

Table 10 shows the actual hours recorded from the beginning by each hospital for maintaining their pneumatic transport system, adjusted to a twelve month average.

TABLE 10

AVERAGE ANNUAL MAINTENANCE HOURS

	Corrective	Preventive	Inspection	Total
St. Mary's	424	284	none	708
Veterans Administration	454	...... 813		1,267
Martin Luther King	171	240	441	852

The above figures clearly reveal that the least amount of corrective maintenance was performed on the heavy wall system at Martin Luther King. The bulk of this was devoted to making changes in certain architectural areas that interfaced with the system, with such changes chargeable to the system. The corrective maintenance time at St. Mary's and the Veterans Administration is almost identical on an annual basis. As can be seen from the following account, in the case of St. Mary's it was used to repair damage to the system caused by excessive vacuum or vibration and the effects on either the tubing and fittings or the mounting hangars; while in the case of the Veterans Administration, it was devoted to basic modifications and replacement of components of the system, such as collectors and diverters. Due to the assignment of personnel on a full time basis at the Veterans Administration, in order to keep the system running, it was virtually impossible to divide the "non-corrective" work between preventive hours and inspection hours.

The most serious operational problems in the Martin Luther King installation were revealed shortly after the hospital started up the system and they cannot be blamed on the system vendor, but rather on architectural designs of surrounding areas.

Laundry was to be collected at the end of the tube line in a plastered room with a closed door. It was discovered that plastered walls lacked the strength to withstand the vacuum pulled by the system. A large steel room was built within the linen collection room to act as a collector and solve the problem.

The original valve rooms were not vented and again the plaster walls would not stand the vacuum pulled through the slide valves. Vented doors have been placed in all such rooms.

The waste bin under the vendor's collector was supplied by the general contractor, not the system vendor, and was constructed with sloping sides which tend to bridge, slowing the drop to the compactor at times.

Materials used in maintenance have been door locks, air valves, and various filters in the system. The filters alone account for 68 percent of all materials used for maintenance.

The Veterans Administration Hospital appears to have had the most drastic changes in the basic design and construction of the system, as a result of maintenance experience showing weaknesses in operation and performance. This might be expected as it is a single tube system, attempting to transport both waste and laundry in the same tube, with great variations in bag weights and cubes between the two products, as well as potential interferences of one with the other.

Shut downs of as long as 30 days occurred during the first 16 months of operation while sections of the system were rebuilt.

At Veterans Administration Hospital, other than the normal replacement of filters, the most prevalent problem has been with diverter valves and the attendant waste and laundry plug-ups which result when these valves malfunction. New diverter valves were installed which are more positive in action and therefore not as prone to jam. Also, a new cyclone collector was installed above the compactor which reduces bag breakage and plug-ups, and problems with the travel timers were rectified.

In addition to plug-ups attributable to problems with the diverter valves, Veterans Administration Hospital also experienced many instances of lighter bags overtaking heavier bags in the tubes, which also causes plugs. Over the 18 month period covered by the maintenance records in our possession, there were a total from all causes of 62 instances of trouble with the tubes plugging, some involving as many as 100 bags of linen. Of these, 35 were cases of linen blockages, 20 were cases if waste bag plugs, and 7 were not identified as to cause. It should be pointed out that the average blockage requires two men seven hours to clear.

The system operating procedures were changed from single bag loading (as is used at St. Mary's) to a keylock multiple bag loading. A single operator per shift was then placed in charge of all chute loading throughout the building. Under the new operating procedures, to avoid the cycling of the diverter valves as much as possible, all linen is supposed to be moved from all floors in the hospital first, starting at the top floor and working down. Following this, the system is shifted to waste transport and all waste is removed, from the top floor down. This reduces wear on the diverter valves and tends to reduce jams.

The downtime of this system is more frequent on the weekend (usually four or five times) than during the week. It is felt that this is related to more efficient operational control of the system during the week.

An examination of the maintenance records of St. Mary's Hospital reveals that most of the trouble with the pneumatic system involves laundry blockages and waste bag plugs. This has resulted in tubes and air lines collapsing, and therefore requiring replacement; as well as seams rupturing, which require riveting or strengthening. Over the 2.16 year period covered by the maintenance records in our possession, there have been a total of 297 instances of trouble with the tubes plugging. Of these, 142 were cases of laundry blockage, 68 were cases of waste bag plugs, and 87 were not identified as to the cause. There were also 14 occasions when either a tube collapsed or a seam split to the point of requiring riveting. In general, St. Mary's has solved all problems of tube plugging and bag breakage by the use of nylon transport bags. However, it is obvious that the 20 gauge metal in the bends and tube of the system is on the light side for trouble-free operation. Further, St. Mary's feels that single bag loading is unnecessarily time consuming for a hospital of this size, resulting in expensive labor waiting to load chute stations.

All three of the pilot systems studied are equipped with fusible link fire dampers, as required. There was no indication that a fire had actually occurred in the systems. However, these fire dampers have been a cause of bag ripping and occasional plugs of the system.

None of the systems appear to have experienced serious shut-downs from electrical or hydraulic line problems. St. Mary's has experienced some freezing weather problems in roof dampers which were corrected by air drying units being installed.

The three systems have entirely different exhauster fan-filter arrangements as well as design of the dampers or valves ahead of the fan to protect the system in case of high vacuum from a plug in the system. The most sophisticated and best working is at Martin Luther King. Fan protection has been 100 percent with the bag filter installed ahead of the fan. No tube damage from plugging has occurred. At Veterans Administration, a rollomatic filter is installed ahead of the fan and appears to operate efficiently. Initially there was no relief valve ahead of the fan at the V.A. and when excess vacuum was drawn as the result of a plug, fan noise and vibration was considerable. This has been corrected by installing a quick acting relief system.

These two systems offer a good comparison between the two types of pre-fan

2 micron filters. Both the bag and the rollomatic filters operate efficiently. However, changing the bag filters appears to involve considerable maintenance labor.

St. Mary's also had a fan relief valve installed ahead of the fan, after the installation was made. It is less sophisticated than the other two and does not appear to work as efficiently. There is no filter ahead of the fan and the lack of it has resulted in fan damage from lint and dust adhering to the fan blades. At one point, the fan became so unbalanced that the vibration cracked the motor base. It appears that a pre-fan filter is a necessity.

Both the Veterans Administration and Martin Luther King discharge directly from the collector to the compactor receiving bin. The slight additional cost for direct discharge appears to greatly improve the operation from a sanitary viewpoint. When the time to cart haul from the collector to the compactor and hand load the compactor (St. Mary's) is factored, it would appear that enough labor could be saved in approximately two and a half years to amortize a direct loading arrangement.

The time required to clear a pneumatic transport system of a plug (either laundry or waste bags) differs considerably between the three hospitals. The surveys that were conducted reveal the absolute necessity of clean-out ports located strategically throughout the system, should plugging occur. Unless these are present, the normal procedure is to either "fish" the bags back to the nearest loading station or, alternatively, to physically remove a section of horizontal tubing in the general location of the plug (if the location can be determined), remove the bags, and reconnect the tube. Obviously, this is extremely time consuming for the maintenance department. Clean-out ports do not appear to be included in the original designs of pneumatic transport systems of the thin wall, full pneumatic type. They are usually included in the designs installed by Envirogenics utilizing gravity to vacuum and heavy wall tubing, and normally they are strategically placed at locations where the horizontal tubing commences a vertical rise. This makes bag removal fairly simple.

All three systems have experienced plugging from improper loading from time to time and it would appear that the principal management solution is to carefully control the personnel using the system.

All have experienced some cross-over between waste ending up in the laundry collector and laundry in the compactor. In the case of St. Mary's and Martin Luther King, this is due 100 percent to operator carelessness in loading the chute doors, as these are double tube systems. In the case of the Veterans Administration, it is felt that the problem has been created by faulty operation of the diverter valve in the single tube system.

As pointed out in the chapter on Design and Construction, the single bag systems are the most costly in labor utilization, and a single tube, single bag system uses the most labor in waiting time of any method. The multiple bag, double tube system is far less expensive to load; with the gravity chute to vacuum tube, and random loading, the least expensive from a labor viewpoint of any method. This is completely borne out in the labor figures for the three hospitals, as can be seen from the chapters on Economics.

All three hospitals are designed differently architecturally but all have at least four vertical wings to service, involving either horizontal walking distances on each floor to vertical chutes installed on a "zoned" basis, or the necessity for at least four vertical risers. The result, as can be seen from the chute station utilization figures, is that a relatively small number of stations carry the bulk of the load and the remaining are installed on a convenience basis. With the multiple bag system installed at two of the hospitals (Martin Luther King and V.A.). the floor pick-up time, and walking time to the chute stations, far exceeds the loading time. At St. Mary's, where considerable waiting time is involved to load the single bag stations, pick-up and walking time is slightly less than loading time.

8-CODES AND REGULATIONS

Solid waste handling in hospitals is affected by a series of codes and regulations. As virtually all construction in a hospital requires a building permit, it involves, normally, submittal of drawings and specifications for the proposed construction and approval of the finished work by regulatory bodies. This usually involves a local building department; the local and/or state fire marshal regulatory bodies, either local or state, concerned with the construction and operation of hospitals; and, if Federal Hill-Burton money is involved, the approval and inspection of the Hill-Burton agency and its regional office.

Probably the most important aspect in such approvals, when solid waste is involved, concerns the fire safety aspects. National fire codes, as published by the National Fire Protection Association (NFPA) are used as the basis for approvals for rubbish handling facilities and incinerators by most local and state jurisdictions. The latest codes are the 1972-1973 version. Building Construction and Facilities are covered in Volume 4, with the standards on incinerators and rubbish handling covered in Standard 82.

Sections 70 and 80 of this Standard cover rubbish or solid waste chutes and systems. Sections 10 and 30 cover incinerators.

It should be noted that NFPA, in their Standard, does not include design criteria for the purpose of reducing air pollution. They state that for such criteria the authorities having jurisdiction should be consulted.

The following paragraphs from Sections 70 and 80 directly apply to solid waste management in hospitals, the control of system design, and the inspection of the facilities by agencies that are guided by the NFPA codes.

70. Rubbish Chutes

701. General

7011. Rubbish chutes are usually employed where there is a relatively large area on each floor from which rubbish is collected. This makes a chute a convenience in handling rubbish in many manufacturing plants, apartment houses, office buildings, and institutions. The procedure is to bring the collected rubbish from each floor to the opening in the chute. The chute then conveys the refuse to its disposition point. A rubbish chute shall serve no other purpose.

7012. There are three types of rubbish chute systems, each with separate fire safety criteria.

a. General Access Gravity Type Rubbish Chute.

b. Limited Access Gravity Type Rubbish Chute.

c. Pneumatic Rubbish Chute.

7013. Definitions.

a. General Access Gravity Type: A rubbish chute of this type is an enclosed vertical passageway in a building to a storage or compacting room where the rubbish is transferred by gravity only. All occupants of the building are free to use the chute at any time.

b. Limited Access Gravity Type: A rubbish chute of this type is an enclosed vertical passageway in a building to a storage or compacting room where the rubbish is transferred by gravity only. Authorized personnel only may use this chute, gaining entry by key to a locked chute door.

c. Pneumatic Rubbish Chute: A rubbish chute of this type has limited access. It may be a vertical, horizontal, or inclined enclosed passageway and having sufficient mechanical applied airflow to convey refuse without clogging to point of disposition.

702. Construction

7021. A steel or steel-jacketed refractory chute may be supported at intervals by the building structure, in which case expansion joints shall be provided at each support level. Other kinds of chutes shall rest upon a substantial noncombustible foundation having a fire-resistance rating of at least 3 hours.

7022. Gravity chutes should be constructed straight and plumb with no offsets whenever possible. If offsets are required they shall deviate not more than 15° from the vertical, and shall be properly reinforced. All chute interiors shall be smooth and without projections.

7023. The size of a refuse chute shall be in accordance with the following:

a. Gravity Type Chutes: The size of the chute shall not be less than 22-1/2 by 22-1/2 inches or 24 inches in diameter inside measurement.

b. Pneumatic Conveyor: The size of the chute shall not be less than 16 inches diameter, inside measurement.

7024. Masonry rubbish chutes shall be constructed of clay or shale brickwork not less than 8 in. thick or of reinforced concrete not less than 6 in. thick. Such chutes shall be lined with firebrick (ASTL Type G, low duty, or the equivalent) not less than 4-1/2 in. thick.

7025.

a. Metal rubbish chutes shall be made of stainless steel or galvanized or aluminum-coated steel with no screws, rivets, or other projections on the interior surface of the chute. Laps or joints shall be of a design so that liquid will drain to the interior of the chute. The steel shall not be lighter than as indicated below:

1. For chutes handling Type 2 or Type 3 wastes, or a combination of both, the portion of a chute located not more than 6 stories below the roof of the building shall be made of steel not lighter than No. 18 gage and any other portion shall be made of steel not lighter than No. 16 gage.

2. Chutes handling wastes other than Type 2 or Type 3 shall be made of steel not lighter than No. 14 gage.

b. Metal chutes may be lined with firebrick (ASTM Type G, low duty or the equivalent) not less than 2-1/2 inches thick. Unlined steel chutes shall be equipped with automatic sprinklers installed in accordance with NFPA Standard No. 13, Section 4310 and other applicable provisions, and the outlet of the chute shall be equipped with a self-closing steel door held open by a fusible link.

c. Rubbish chutes may be made of listed medium-heat appliance chimney sections approved for this use.

d. Rubbish chutes, other than masonry chutes conforming to 7024 or constructed of masonry walls having a fire resistance rating not less than specified below, shall be enclosed in all stories above the storage or compacting room within a continuous enclosure constructed of materials which are not combustible, such as masonry, and extending from the ceiling of the storage or compacting room to or through the roof so as to retain the integrity of the fire separation as required by applicable building code provisions. The walls of the enclosure or the walls of the masonry chute shall have a fire resistance rating of not less than 1 hour if the building is less than 4 stories in height and not less than 2 hours if the building is 4 or more stories in height. Any opening in the enclosing walls shall be equipped with self-closing fire doors approved for Class B openings.

7026. A rubbish chute shall extend (full size) at least 4 ft. above the roof of the building. The chute shall be open to the atmosphere.

703. Service Openings

7031. Service openings shall be provided in accordance with the following criteria:

a. General Access Gravity Chutes: All service openings into a rubbish chute shall be provided with a self-closing, self-latching, bottom-hinged hopper-type door approved for Class B openings and having a rating of not less than 1 hour with "Temperature rise: 30 min.-250° F max." The door frame shall be firmly built into the chute and the design and installation shall be such that no part of the frame or door will project into the chute.

b. Limited Access and Pneumatic Chutes: All service openings into a rubbish chute shall be provided with self-closing, self-latching doors approved for Class B openings and having a rating of not less than one hour with "Temperature rise: 30 min.-250° F max." The door frame shall be firmly built into the chute and the design and installation shall be such that no part of the frame or door will project into the chute.

7032. The area of each service opening shall be limited to one-third of the cross-sectional area of the chute.

7033. Every service opening shall be enclosed in a room or compartment separated from other parts of the building by walls and floor and ceiling assemblies having a fire-resistance rating of not less than 1 hour with openings to such room or compartment protected by approved fire doors suitable for Class B openings.

704. Chute Terminal Rooms or Bins

7041. Rubbish chutes shall terminate or discharge directly into a room or bin separated from the incinerator room and from other parts of the building by walls and floor and ceiling assemblies having a fire-resistance rating equal to that specified for the chute. Openings to such rooms or bins shall be protected by approved self-closing or automatic fire doors suitable for Class B openings.

7042. Rubbish chutes other than charging chutes covered in Section 40 and combined chimney flue and charging chute covered in Section 50 shall not discharge directly into an incinerator.

705. Automatic Feeding or Stoking Systems

7051. Systems for the automatic transfer of waste materials from a rubbish-chute terminal room or bin to an incinerator or other means of automatic feeding or stoking incinerators shall not be installed unless special permission of the authority having jurisdiction has been obtained.

NOTE: There may be situations where arrangements are made for handling refuse mechanically and automatic stoking of incinerators which would not introduce an unreasonable hazard. In such cases, the authority having jurisdiction may permit such an arrangement, taking into consideration the whole layout, its relation to the rest of the building, the presence or absence of complete sprinkler protection, the continuity and competence of the personal supervision attending the operation, ventilation, access for fire fighting, and similar factors. See also Standard for Installation of Blower and Exhaust Systems for Dust, Stock, and Vapor Removal, NFPA No. 91.

706. Automatic Sprinklers

7061. Automatic sprinklers, properly installed, provide a reliable and effective means for fire extinguishment and shall be installed in chute terminal rooms or bins. A short length of hand hose connected to a suitable water supply should also be provided. Fires of the nature likely to occur at chute terminals are generally difficult to control by ordinary means due to the large amount of smoke evolved and consequent difficulty of access by the fire department. Automatic extinguishment of such fires in the incipient stage is, therefore, of primary importance.

80. Rubbish Handling

803. Rubbish Receptacles

8035. Wastebaskets and small containers for rubbish should be of noncombustible material. Large quantities of rubbish shall be handled in metal ash cans, drums, or similar containers.

8037. Approved waste cans and receptacles shall be provided for oily waste and other materials requiring special handling.

8038. Barrels and similar containers for rubbish and ashes shall be substantial, approved metal construction, maintained in good condition and provided with handles and a cover. They shall be provided with a flange at the bottom to provide at least a 2-in. air space between the bottom and the floor. Containers and barrels shall be kept covered.

804. Bailing and Compacting

8041. The location of rooms for the collection and baling or compacting of refuse should be given careful consideration to avoid creating an exposure hazard to the rest of the building. Quick-burning fires of the flash variety are to be expected where waste paper is handled in large quantities.

8042. If a rubbish room or bin is not provided, refuse shall be stored in covered metal cans only.

8043. Rooms used for baling or compacting shall be cut off from the rest of the building by ceilings, floors, and walls, the minimum fire resistance of which is 2 hours, with door openings protected by fire doors suitable for Class B openings.

8044. Automatic sprinklers, properly installed, provide a reliable and effective means for fire extinguishment and shall be installed in baling and compacting rooms. A short length of hand hose connected to a suitable water supply should also be provided. Fires of the nature likely to occur in baling and compacting rooms are generally difficult to control by ordinary means due to the large amount of smoke evolved and consequent difficulty of access by the fire department. Automatic extinguishment of such fires in the incipient stage is, therefore, of primary importance.

The foregoing discusses national codes and regulations and only those pertaining to fire safety.

In addition, there are literally hundreds of additional regulations pertaining to waste handling in hospitals, promulgated in municipalities, counties, and states, by various governmental boards and agencies covering the regulation of health facilities and the control of the environment. Health departments have published regulations affecting both the in-house handling practices, as well as off-site removal; environmental control bodies have concentrated on off-site handling practices. All hospitals should be aware of all such regulations to ensure they are in compliance when they install methods for waste management.

9- ENVIRONMENTAL TESTING

The hazardous nature of a large proportion of hospital solid waste and possible environmental effects has been established through various studies that have been performed over the past 15 years. The effect on the hospital environment of the use of a pneumatic system, transporting encapsulated solid waste, has not been completely documented in past studies.

Environmental effects from such a system may be classified under three general headings. First the systems involve machinery; in particular, fans moving moderately heavy loads at high speed within closed metal tubes. The increased noise (if any) that this creates in the hospital environment must be measured. Secondly, it has been established in other studies that solid waste contains many odor-causing components. If the encapsulating method is destroyed in the system, or if housekeeping practices are unsatisfactory, possibilities exist that an odor condition may develop. Thirdly, the system consists of chutes opening onto nursing areas, closed tubes, and collector boxes joined to fans that exit the air from the system. With possibilities of bag breakage within the system, coupled with a lack of self-cleaning and sanitizing devices, bacterial contamination of the hospital environment is a possibility. The survey team conducted tests within each of the hospitals in these three areas; noise level readings were taken; odor readings were registered; and bacterial counts made of both the pneumatic system and the adjacent area. In addition, notations were made of the presence or absence of dust and litter (including ruptured waste bags) along with any physically unsafe or hazardous conditions, including any problems in transporting and disposing of chemical and toxic wastes.

SOUND LEVEL READINGS

In an institutional setting such as a hospital there are many areas and many times of day where "quiet" or a lack of sound is desired to assist in the recovery of patients, or simply to avoid interference with staff activities, such as conversations.

Sound or "noise" is caused by a variation in atmospheric pressure. It may be sudden and extremely loud, such as gunfire. It may be at a constant level that a person "gets used to" and finally does not even notice. It may be, in either case, of a level and frequency that can be dangerous to the point of causing a loss of hearing, suddenly or gradually. Or it may be merely annoying, such as a faucet dripping, or chalk squeaking against a blackboard, and not have any permanent effect on the listener's hearing.

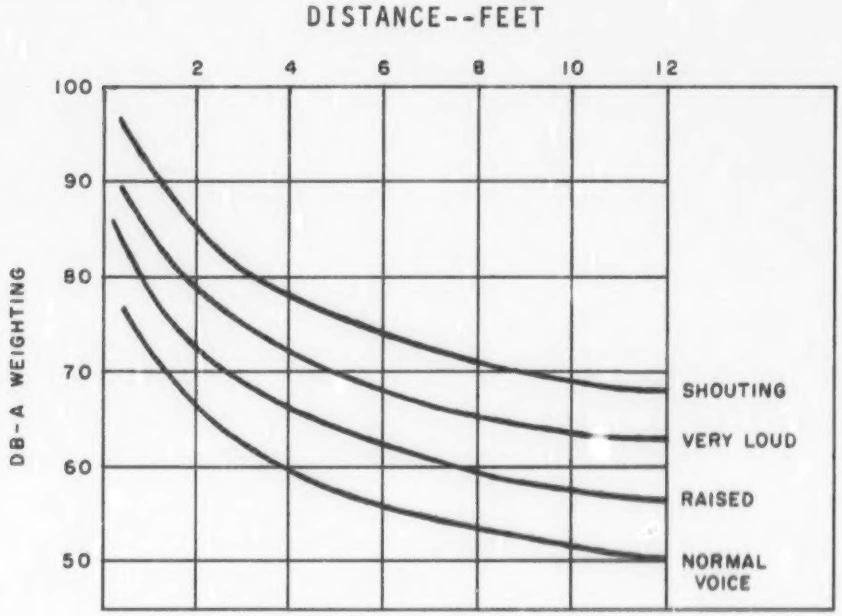

FIGURE 17. CURVES SHOWING HOW NOISE INTERFERES WITH SPOKEN OR SHOUTED CONVERSATION

Before we can evaluate the possible effects of sound on hearing, or discomfort, we must know three things about it: (a) the sound pressure level; (b) the frequencies present in the sound, from low pitch to high; and (c) the duration of the sound at these frequencies and pressure levels.

To measure sound pressure, an instrument known as a "sound level meter" is used. This is an electronic ear that converts sound into electrical signals and displays them on a dial. The levels are expressed in decibels (dB), an arbitrary measuring unit, in a scale from 0 to 140. The weakest sound that a person with excellent hearing can detect in an extremely quiet location is assigned the 0-dB value. At 140-dB the threshold of pain is reached in hearing. In between are the levels found in institutions, homes, offices, and factories, ranging from 50- to 60-dB as a typical office noise level, to a power lawn mower at around 100-dB, or a riveting machine at 118-dB, which is the discomfort level.

Coupled with sound pressure level is the frequency or pitch of the sound. This is measured in "hertz" units. The frequency has much to do with how loud a sound appears to be to the ear. The higher the frequency, the more annoying and the more physical effect on the human hearing. The human ear can tolerate more low frequency sound than high.

Hence, the more sophisticated meters for measuring sound levels have built-in weighing networks that permit responding to some frequencies more than others, similar to the reaction of the human ear. Acoustical standards have established three such networks and designated them "A," "B," and "C." Very low frequencies are severely suppressed or discriminated against in the "A" network (as the human ear would do); they are moderately discriminated against in the "B" network; and they are accepted in the "C" network, which gives a flat response across all frequencies.

If the sound level being measured is higher on the "C" network than on the "A," the noise source is predominantly at the low frequencies (below 600 hertz), since the "A" network discriminated against the low frequencies and give a lower dB reading. If the readings on the sound level meter are progressively higher, going from "A" to "B" to "C" networks, then the predominant portion of the sound source is below 600 hertz in frequency. If, on the other hand, the readings on all three networks are close together in dB, it indicates that the sound energy is of a higher frequency (above 600 hertz).

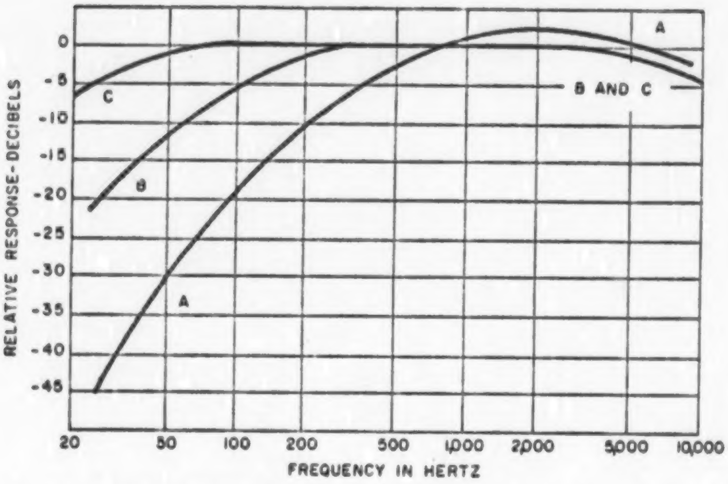

FIGURE 18

FREQUENCY RESPONSE FOR A, B, AND C NETWORKS WEIGHTING CHARACTERISTICS.

As stated, sound levels and frequencies present two problems in a hospital complex: they may be annoying to patients, staff, and visitors; or they may be dangerous to the level of damaging hearing. To prevent hearing damage, Federal regulations under the Occupational Safety and Health Act (OSHA) of 1970 set permissible noise limits to protect the workers in any place of employment.

TABLE 11 PERMISSIBLE NOISE EXPOSURES

Duration, per Day, Hours	Sound Level in dB(A), Slow Response
8	90
6	92
4	95
3	97
2	100
1-1/2	102
1	105
1/2	110
1/4 or less	115

When sound levels and duration exceed those values given above, protection against the effects of noise exposure must be provided and a continuing, effective hearing conservation program must be administered.

To determine how much sound the pneumatic transport systems generate in each of the three survey hospitals, sound level readings were taken inside and outside each chute loading room; inside and outside the rooms containing collector boxes and compactors; in the mechanical rooms that contain the motors and exhaust fans; and at the exit side of the fan exhaust outside each building.

The instrument used in this survey was a Type 2 Sound Level Meter meeting Standard S1.4-1971 of the American National Standards Institute (ANSI). It was calibrated twice each day during the survey. All readings were taken with the equipment operating and waste bags going down the chutes.

The following tables present the reduced data obtained during the survey. The first table for each hospital contains data taken within each chute room, 3 to 5 feet from the hopper loading door. It shows the maximum, minimum, and average dB readings on all three networks for all loading stations *on each floor* of the hospital.

The second table for each hospital contains maximum, minimum, and average dB values of all three networks *for each vertical chute* within the hospital, covering all floors through which the chute passes. Here it can be seen that the average dB values, for all three networks, for all three hospitals, are consistently close together and vary within any one hospital by only a few dB's. There is a difference *between* hospitals, due to the different types of systems installed.

The third and fourth tables for each hospital present data in the same format as the first and second tables, but the readings were taken outside the chute rooms, 3 to 5 feet from the outside door of the chute room.

The average readings outside the rooms were consistently lower than those inside, for all three hospitals. The difference between inside and outside average readings was more pronounced at St. Mary's and Veterans Administration Hospitals than at Martin Luther King Hospital. This is attributed to the fact that the gravity to vacuum system at Martin Luther King, with its absence of vacuum noise at the loading hoppers, proved to be a very quiet system even inside the chute rooms.

The method of taking sound readings also indicated that, regardless of the type of pneumatic system, there was virtually no correlation between the vertical distance a bag drops and the sound level produced.

An examination of the first four tables for all hospitals will show peaks and valleys among the data. As an example, one can see that the highest A-network noise level inside a chute room at Martin Luther King occurred at the fourth floor in Wing A and was 72 dB(A). This may be considered against an average of 66 dB(A) for the entire fourth floor, or against 63 dB(A) for the entire Wing A. Peaks of this nature occurred in all the hospitals surveyed.

Several elements contribute to these peaks. Architectural considerations creating acoustical differences can and do occur. Different methods of hanging the chutes also contribute. An important contributing factor to sound level variations was found to be the actual content of the waste bag going down the chute. Those that contained a large amount of hard plastic and cans not only created a higher sound level but in most cases could be heard going all the way down the chute.

It will be noted that the dB readings consistently increase as the meter recorded sound from the A to the B to the C networks. This is a clear indication that the sound caused by bags of waste traveling through the system, both vertically and horizontally, is predominantly in the low frequency range (below 600 hertz) and is relatively tolerable to the human ear. The sound from each bag is relatively sudden, of quite short duration, and with little continuing reverberation or echo effect. Even though bags may be transported constantly over an 8-hour day, the maximum readings are well below OSHA permissible noise exposure levels.

On the other hand, as seen from the A-network, the maximums in the corridor are from 62 dB(A) to 71 dB(A), which is approaching the "annoyance" level for quiet conversation or a resting patient. Therefore, physical locations of chutes and tubes should always consider this.

TABLE 12

ST. MARY'S HOSPITAL

Load Station Sound Level Analysis
Inside Chute Rooms, 3'-5' from Loading Hopper Door

All Stations on Floor	A-Network, dB(A) Max.	A-Network, dB(A) Min.	A-Network, dB(A) Avg.	B-Network, dB(B) Max.	B-Network, dB(B) Min.	B-Network, dB(B) Avg.	C-Network, dB(C) Max.	C-Network, dB(C) Min.	C-Network, dB(C) Avg.
1.	78	67	71	79	70	74	82	77	80
2.	77	74	75	81	74	77	85	77	80
3.	73	66	70	73	68	71	75	72	73
4.	72	70	71	75	70	73	76	73	75
5.	70	61	65	70	65	67	75	68	72
6.	74	69	72	74	71	73	76	74	75
7.	72	69	71	73	72	73	76	74	75
8.	70	70	70	75	75	75	75	75	75
9.	71	71	71	71	71	71	72	72	72
10.	70	70	70	73	73	73	74	74	74
Averages	73	69	70	74	71	72	76	73	75

All Stations, Each Vertical Chute	A-Network, dB(A) Max.	A-Network, dB(A) Min.	A-Network, dB(A) Avg.	B-Network, dB(B) Max.	B-Network, dB(B) Min.	B-Network, dB(B) Avg.	C-Network, dB(C) Max.	C-Network, dB(C) Min.	C-Network, dB(C) Avg.
West Wing	78	61	71	79	67	73	82	68	74
Center Wing	74	65	69	75	65	71	77	72	74
East Wing	77	67	71	81	70	73	85	73	77
Averages	76	64	70	78	67	72	81	71	75

Load Stations Sound Level Analysis
Outside Chute Rooms, 3'-5' from Outside Door

All Stations on Floor	A-Network, dB(A) Max.	A-Network, dB(A) Min.	A-Network, dB(A) Avg.	B-Network, dB(B) Max.	B-Network, dB(B) Min.	B-Network, dB(B) Avg.	C-Network, dB(C) Max.	C-Network, dB(C) Min.	C-Network, dB(C) Avg.
1.	62	59	60	67	65	66	77	72	74
2.	66	59	63	68	64	66	74	68	70
3.	61	59	60	62	60	61	64	63	64
4.	65	63	64	65	65	65	68	66	67
5.	65	59	61	62	59	61	67	63	65
6.	61	59	60	65	62	64	66	66	66
7.	69	65	67	66	66	66	70	70	70
8.	61	61	61	61	61	61	64	64	64
9.	60	60	60	59	59	59	70	70	70
10.	60	60	60	61	61	61	64	64	64
Averages	63	60	62	64	62	63	68	67	67

All Stations, Each Vertical Chute	A-Network, dB(A) Max.	A-Network, dB(A) Min.	A-Network, dB(A) Avg.	B-Network, dB(B) Max.	B-Network, dB(B) Min.	B-Network, dB(B) Avg.	C-Network, dB(C) Max.	C-Network, dB(C) Min.	C-Network, dB(C) Avg.
West Wing	69	59	62	67	59	63	73	64	68
Center Wing	65	59	62	68	61	64	72	64	65
East Wing	65	59	61	67	59	63	77	63	69
Averages	66	59	62	67	60	63	74	64	67

TABLE 13

MARTIN LUTHER KING HOSPITAL

Load Station Sound Level Analysis
Inside Chute Rooms, 3'-5' from Loading Hopper Door

All Stations on Floor	A-Network, dB(A) Max.	Min.	Avg.	B-Network, dB(B) Max.	Min.	Avg.	C-Network, dB(C) Max.	Min.	Avg.
Basement	63	63	63	63	63	63	67	67	67
1.	70	63	65	72	63	66	72	67	69
2.	62	58	60	64	63	64	69	65	67
3.	66	58	62	69	59	64	77	60	68
4.	72	62	66	68	64	66	65	63	64
5.	64	64	64	67	66	67	70	69	70
Averages	66	61	63	67	63	65	70	65	67

All Stations, Each Vertical Chute	A-Network, dB(A) Max.	Min.	Avg.	B-Network, dB(B) Max.	Min.	Avg.	C-Network, dB(C) Max.	Min.	Avg.
Segment I	70	62	65	72	64	68	77	64	70
Wing A	72	59	63	64	59	63	67	60	65
Wing B	68	58	62	67	63	65	71	65	68
Wing C	64	58	61	65	63	64	69	63	66
Averages	69	59	63	67	62	65	71	63	67

Load Station Sound Level Analysis
Outside Chute Rooms, 3'-5' from Outside Door

All Stations on Floor	A-Network, dB(A) Max.	Min.	Avg.	B-Network, dB(B) Max.	Min.	Avg.	C-Network, dB(C) Max.	Min.	Avg.
Basement	62	62	62	62	62	62	64	64	64
1.	62	58	61	62	56	60	64	57	62
2.	63	57	60	64	58	61	67	64	66
3.	64	58	61	66	60	64	69	61	66
4.	60	58	59	64	57	61	68	64	65
5.	59	58	59	60	59	60	65	64	65
Averages	62	59	60	63	59	61	66	62	65

All Stations, Each Vertical Chute	A-Network, dB(A) Max.	Min.	Avg.	B-Network, dB(B) Max.	Min.	Avg.	C-Network, dB(C) Max.	Min.	Avg.
Segment I	59	58	58	62	56	59	67	57	64
Wing A	62	5[illegible]	60	64	58	61	68	61	64
Wing B	62	58	59	66	59	62	69	64	65
Wing C	63	59	62	66	60	64	66	64	66
Averages	62	58	60	64	58	61	67	62	65

TABLE 14

VETERANS ADMINISTRATION HOSPITAL

Load Station Sound Level Analysis
Inside Chute Rooms, 3'-5' from Loading Hopper Door

All Stations on Floor	A-Network, dB(A)			B-Network, dB(B)			C-Network, dB(C)		
	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
1.	76	73	75	78	75	77	84	82	81
2.	89	80	85	81	72	78	90	87	88
3.	85	78	83	87	75	80	90	86	89
4.	81	75	77	87	76	80	85	79	82
5.	79	70	73	82	75	78	83	76	78
6.	78	70	74	80	77	79	87	79	84
Averages	82	74	78	83	75	79	87	82	84

All Stations, Each Vertical Chute	A-Network, dB(A)			B-Network, dB(B)			C-Network, dB(C)		
	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
North Wing	89	76	81	87	72	79	90	79	84
West Wing	88	73	79	81	75	77	90	82	85
South Wing	80	70	75	80	75	77	88	76	83
East Wing	85	70	76	87	78	81	90	76	85
Averages	86	72	78	84	76	79	90	78	84

Load Station Sound Level Analysis
Outside Chute Rooms, 3'-5' from Outside Door

All Stations on Floor	A-Network, dB(A)			B-Network, dB(B)			C-Network, dB(C)		
	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
1.	77	55	66	78	60	69	79	69	74
2.	65	56	61	68	62	66	78	71	75
3.	72	60	66	76	63	72	79	69	74
4.	68	62	65	77	69	72	74	72	73
5.	69	62	65	75	63	69	76	71	74
6.	68	61	65	70	69	70	76	71	73
Averages	70	59	65	74	64	70	77	71	74

All Stations, Each Vertical Chute	A-Network, dB(A)			B-Network, dB(B)			C-Network, dB(C)		
	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
North Wing	68	56	63	76	63	68	79	73	75
West Wing	77	62	69	78	68	72	79	72	75
South Wing	68	60	63	70	63	68	74	69	71
East Wing	69	55	54	77	60	70	78	69	74
Averages	71	58	65	75	64	70	78	71	74

The fifth table for each hospital presents maximum, minimum, and average data on each network, for the fan (or equipment rooms), the collector, and the compactor areas. Readings were taken in several locations within each room, 5 to 10 feet from the operating equipment. The sixth table presents data for the same pieces of equipment, with readings taken 10 feet from outside the area with the equipment running. As might be expected, all these areas are noisy ones. The fans used in these systems are high-horsepower fans which create noise when running. Collectors have metallic dampers which bang loudly when they open and close. The rams on all the compactors were noisy. The dB(A) readings in the fan rooms in all hospitals were at least 95 dB(A) average, and at one hospital it was as high as 104 dB(A). All of these are at a level where noise protection for workers is required by OSHA if workers must remain in these areas for extended periods. Even short, yet constant, periods of exposure might be harmful to an individual worker over a period of months or years. A worker should not remain in the 95 dB(A) fan room in excess of four hours in any day or the 104 dB(A) fan room in excess of one hour.

The fan rooms of two of these hospitals were on or near the roof, where they are not likely to annoy anyone. Happily, this includes the noisiest one at 104 dB(A)--which, incidentally, does not have a sound attenuator. The fan room for the third hospital (Martin Luther King) is at ground level, in a small service building. This service building is located approximately 40 feet from a brick wall at the edge of the hospital property and beyond which is a residential area of small homes. A series of readings was taken at this wall, 40 feet from the fan attenuator. The average readings at this point were 76 dB(A), 77 dB(B), and 80 dB(C). These readings are sufficiently high to be annoying to some people.

In general, the analysis shows that Martin Luther King Hospital, with its gravity to vacuum system, has the quietest system. Veterans Administration Hospital, with a full-vacuum single-tube system with diverter valves, was the noisiest, while St. Mary's Hospital, with a small-tube full-vacuum and using nylon mesh bags in the chutes, was in the middle. Because of the consistent increase in dB readings from A-network to B-network to C-network in all hospitals, it is concluded that most, but not all, of the sound is of a low frequency variety which is not so annoying to most individuals. The general dB levels throughout patient areas of all three hospitals are considered to be sufficiently low as to not cause annoyance, with the possible exception of Veterans Administration Hospital, which may cause problems in some areas. It was observed at Martin Luther King Hospital that both the automatic cart system and the tote box system were a higher noise level source than the pneumatic tube system.

TABLE 15

MARTIN LUTHER KING HOSPITAL

SOUND LEVEL ANALYSIS OF FANS, COLLECTORS, AND COMPACTORS

INSIDE ROOMS, 5' - 10' FROM EQUIPMENT

Equipment Name	A-Network, dB(A)			B-Network, dB(B)			C-Network, dB(C)		
	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
Fan	95	94	95	96	95	96	100	98	99
Collector	103	94	98	98	93	96	101	94	97
Compactor	103	94	98	98	93	96	101	94	97

TABLE 16

MARTIN LUTHER KING HOSPITAL

SOUND LEVEL ANALYSIS OF FANS, COLLECTORS, AND COMPACTORS

OUTSIDE ROOMS, 10' AWAY

Equipment Name	A-Network, dB(A)			B-Network, dB(B)			C-Network, dB(C)		
	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
Fan	86	70	77	87	72	79	89	76	82
Collector	72	68	70	75	71	73	84	75	78
Compactor	72	68	70	75	71	73	84	75	78
Sound attenuator, ground level	89	73	82	91	74	83	95	79	87

TABLE 17

ST. MARY'S HOSPITAL

SOUND LEVEL ANALYSIS OF FANS, COLLECTORS, AND COMPACTORS

INSIDE ROOMS, 5'-10' FROM EQUIPMENT

Equipment Name	A-Network, dB(A)			B-Network, dB(B)			C-Network, dB(C)		
	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
Fan	106	101	104	108	106	107	110	107	108
Collector	70	69	70	76	73	74	81	80	80
Compactor	75	70	72	77	72	75	85	78	82

TABLE 18

ST. MARY'S HOSPITAL

SOUND LEVEL ANALYSIS OF FANS, COLLECTORS, AND COMPACTORS

OUTSIDE ROOMS, 10' AWAY

Equipment Name	A-Network, dB(A)			B-Network, dB(B)			C-Network, dB(C)		
	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
Fan	79	68	74	85	77	82	88	86	87
Collector	Constant ambient noise was louder than collector.								
Compactor	75	70	72	77	72	75	85	78	82
Sound attenuator	None installed. Effluent air on roof. Sound level approximately same as figures given above, outside fan room.								

TABLE 19

VETERANS ADMINISTRATION HOSPITAL

SOUND LEVEL ANALYSIS OF FANS, COLLECTORS, AND COMPACTORS INSIDE ROOMS, 5'-10' FROM EQUIPMENT

Equipment Name	A-Network, dB(A)			B-Network, dB(B)			C-Network, dB(C)		
	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
Fan	96	94	95	96	96	96	98	97	98
Collector	92	80	86	91	87	88	92	89	91
Compactor	92	80	86	91	87	88	92	89	91

TABLE 20

VETERANS ADMINISTRATION HOSPITAL

SOUND LEVEL ANALYSIS OF FANS, COLLECTORS, AND COMPACTORS OUTSIDE ROOMS, 10' AWAY

Equipment Name	A-Network, dB(A)			B-Network, dB(B)			C-Network, dB(C)		
	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
Fan	95	94	95*	101	99	101*	103	101	102*
Collector	81	77	78	81	78	79	84	79	81
Compactor	81	77	78	81	78	79	84	79	81
Sound attenuator, on roof	73	73	73	84	84	85	91	91	91

* The area 10' outside the door to the fan room contains three air compressors, which contributed to the overall sound pressure level and accounts for these average dB readings outside the fan room being generally higher than the corresponding ones inside the fan room.

ODOR DETECTION

The solid waste generated in hospitals contains many items capable of producing a variety of odors. Although all three hospitals surveyed place their solid waste into plastic bags prior to depositing them in the pneumatic tube system, there is a very real possibility that some of these encapsulated items might become free at some points in the system and create a noxious odor which could be detectable by, and annoying to, patients or staff in the vicinity. All three of the hospitals in the survey have experienced occasional problems in the past with the plastic solid waste bags breaking, ripping, or coming open either while being loaded into the chutes or at some point during their transit of the system. As examples, a bag can break when it hits the slide valve in a gravity to vacuum system; it can break when it hits a diverter valve in a single tube system; it can break when it enters the collector box at a speed of as much as 80 feet per second. Further, the bag can contain glass, other breakable objects, and liquids. The management practices in many hospitals do not permit glass and liquids to be placed into the tube system. Nevertheless, people continue to do so occasionally. At one of the hospitals in this study, the survey team observed the face of a slide valve which was covered with dried blood, feces, liquids, and other wastes. This valve room had a moderate but definite odor.

For these reasons, the survey team, using techniques developed in the past, performed odor detection tests in all three hospitals. These tests were carried out at each chute loading station, inside and outside of the collector boxes, adjacent to the compactors, in the fan rooms, and in the effluent air downstream of the fan. The results of these qualitative tests, which represent the presence of odor in the air, were translated into a numerical code ranging from 1 to 5, as defined in Chapter 12 of the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) Handbook of Fundamentals. The code values are defined as follows:

1 = No odor present

2 = Threshold, or just recognizable odor present

3 = Slight odor present

4 = Moderate odor present

5 = Strong odor present

In addition, while determining the odor readings, the survey team made note of the presence or absence of dust, litter, ruptured waste bags, and any physical hazards directly attributable to the pneumatic systems.

At Veterans Administration Hospital, San Diego, odor detection readings were taken at a total of 28 locations. Of these, no odor was present at 13 locations, or 46 percent of the total readings. There were 9 locations, or 32 percent of the total, where there was just a recognizable odor present (Code 2). Four locations, or 14 percent of the total, had a slight odor present (Code 3). Only one loading station (6W) had a reading as high as Code 4 (moderate odor present). Strong odor (Code 5) was detected at the collector box leading into the compactor. Overall, 93 percent of all locations tested had only a slight odor, or less.

At Martin Luther King Hospital, Los Angeles, odor detection readings were taken at a total of 36 locations. Of these, no odor was present at 13 locations, or 36 percent of the total readings. There were 17 locations, or 47 percent of the total, where there was a just recognizable odor present (Code 2). One location, or 3 percent of the total, had a slight odor present (Code 3). This reading was taken directly behind the compactor. There were four locations, or 11 percent of the total readings, which had a moderate odor present (Code 4). Only one of these Code 4 locations was inside the hospital proper and occurred inside the chute loading room on the fourth floor in Wing A. This location also had the highest sound level reading of all chute loading rooms inside the hospital, but this appeared to be a coincidence since no correlation between sound level and odor level could be determined at this loading room. The remaining locations with Code 4 odor readings were in the effluent air downstream of the sound attenuator and in one slide valve room (Room 50-57). This is the slide valve mentioned in the introduction to this section which had wastes on its face caused by bag breakage. The Code 4 readings obtained in the effluent air were taken at locations directly behind and under the sound attenuator and at a spot approximately 40 feet west of the attenuator. This latter location is close to a group of private homes, the residents of which could be annoyed by this Code 4 odor. This situation probably could be alleviated by more frequent disinfectant spraying of the compactor and dust filter.

Strong odor (Code 5) was detected at the collector leading into the compactor. Overall, 86 percent of all locations tested had only a slight odor, or less.

At St. Mary's Hospital, Duluth, odor detection readings were taken at a total of 30 locations. Of these, no odor was present at 14 locations, or 47 percent of the total readings. There were 11 locations, or 37 percent of the total, where there was a just recognizable odor present (Code 2). Three locations, or 10 percent of the total readings, had a slight odor present (Code 3). These occurred inside chute loading rooms on the third floor of the West wing, the fifth floor of the East wing, and the ninth floor of the West wing.

Moderate odor (Code 4) was detected at the collector box, and strong odor (Code 5) was detected at the compactor. Overall, 93 percent of all locations tested had only a slight odor, or less.

Not all of the odors detected in the three hospitals were necessarily noxious, unpleasant, or annoying. A few were caused by bars of soap being stored in the chute room, and these were subjectively judged by the survey team to be actually pleasant odors. Others were caused by such things as ether, various antiseptics, and soiled linens, as well as the components of solid waste.

Overall, because of the relatively low odor code readings obtained, it is our opinion that none of the three hospitals surveyed have a significant odor problem within the hospital itself that can be attributed to the pneumatic solid waste transport system. Most of the moderate and strong, unpleasant type odors were associated with the "end of the line" equipment, away from areas occupied by patients and staff. The most significant of these was the situation described above at Martin Luther King, where there is a potential of annoying occupants of nearby homes.

Table 21 gives a summary of the occurrences of various odor levels in the three hospitals:

TABLE 21

SUMMARY OF OCCURRENCES OF VARIOUS ODOR LEVELS

Odor Code	V.A. HOSPITAL		MARTIN LUTHER KING HOSPITAL		ST. MARY'S HOSPITAL	
	No. of Occurrences	% of Total	No. of Occurrences	% of Total	No. of Occurrences	% of Total
1.	13	46%	13	36%	14	47%
2.	9	32%	17	47%	11	37%
3.	4	14%	1	3%	3	10%
4.	1	4%	4	11%	1*	3%
5.	1**	4%	1**	3%	1**	3%
Totals	28	100%	36	100%	30	100%

* Trash collector box

** Compactor

THE PROBLEMS CREATED BY AEROSOLS

In pneumatic tube systems, whether it is a gravity to vacuum system or a full vacuum system, there is a constant negative pressure in the system when it is operating. This assures that air is always pulled from the load stations toward the waste collector. Therefore, with these type systems, the problem found in straight gravity chutes, in which air in the chute contaminates the load stations, does not exist if the system is functioning properly.

As seen, since basically the tubes do not leak, the major aerosol problems with these pneumatic systems appear to exist at the end of the line, principally in two areas. First, leakage generally occurs between the waste collector and reduction equipment, whether this equipment is an attrition mill, a compactor, or an incinerator. Second, problems can occur in the fan-mechanical room, where effluent air from the system is exhausted into the ambient atmosphere adjacent to the hospital. There not only are leakages around the fan itself, the exit ducts, and sound attenuators, but there are often filters, with potentially high bacteriological counts, and which must be manually changed and disposed of.

HOUSEKEEPING PRACTICES

The methods used in each hospital to control the environmental conditions, to keep the areas clean, and to manage failures or weaknesses in the pneumatic systems that cause bag breakage and the spread of waste and possible contamination, were observed by the survey team during each site visit. As has been stated repeatedly in this report, the most automated system for transporting and collecting waste is subject to various weaknesses, caused by human error or by mechanical, electrical, and design weaknesses affecting the equipment and the safe encapsulation of every bag of waste. Further, the equipment itself may provide unsafe working conditions by the manner in which it operates.

VETERANS ADMINISTRATION HOSPITAL

One broken waste bag was observed at Veterans Administration Hospital. This bag was lying on the floor of the laundry room, directly under the linen collector. The bag was completely ruptured and its contents spread over an area of approximately 25 square feet. Laundry workers cleaned up the mess (wearing gloves to do so) while the team was still present. This hospital, with its single-tube system, frequently has cross-over problems, with laundry bags going to the compactor and waste bags going to the laundry. While the survey team was in the laundry, the doors of the linen collector opened six times but instead of laundry bags coming down, a moderate amount of loose trash, paper, and dust floated out. This was also swept up by the laundry workers.

No unsafe or hazardous conditions were seen. There was no visible dust inside the hospital other than that coming from the linen collector. The effluent air filter on the roof, however, was approximately 80 percent covered by a heavy layer of thick dust. This restricts air flow and obviously affects the efficiency of the pneumatic system. This was immediately brought to the attention of hospital management by the survey team so that the filter could be either cleaned or changed.

MARTIN LUTHER KING HOSPITAL

No broken waste bags were actually seen by the environmental testing team. However, as mentioned previously, bags containing unauthorized waste had obviously broken in the past on the face of one slide valve.

No unsafe or hazardous conditions were found except in the slide valve rooms. There are two such valves in each valve room, one for waste and one for soiled laundry. The valves consist of heavy, 20 in. diameter metal plates which are automatically controlled. When they are activated they swing rapidly, and without warning, out of the chutes and into the small room. Even though there are signs posted in the valve rooms warning of this danger, a person who is unfamiliar with the operation of these large automatic valves, or even one who is familiar but may become careless because of this familiarity, could be struck and seriously injured by the valve plates when they swing out. This situation could be alleviated by placing a wire mesh screen around the areas covered by the valve plate when it swings out. Such a screen should have a removable section so that maintenance personnel can periodically clean the valve face.

ST. MARY'S HOSPITAL

No broken bags, litter, dust, or unsafe conditions attributable to the pneumatic solid waste transport system were observed anywhere in this hospital. St. Mary's had established the practice of placing their plastic solid waste bags, several at a time, inside large, heavy nylon mesh bags prior to depositing them in the chutes. As can be seen from the chapter on Economics, these nylon mesh bags are a significant item of expense, amounting to 25 percent of the average total direct costs per year to operate the pneumatic solid waste transport system. Nevertheless, the practice appears to have solved the problem of bag breakage and ripping, and also appears to be a causative factor in lower sound levels in the chutes.

BACTERIOLOGICAL TESTING

Many researchers have considered the fact that up to 15 percent of raw hospital waste is potentially infectious, and that from 2 to 8 percent of the total, due to the nature of the waste products and their generation points, has proven pathogenic organisms present in high concentrations, particularly if an organic substrate is present. Tests of waste samples have shown that Bacillis organisms are most prevalent, particularly streptococci and staphylococci, with *Staphylococcus aureus* the predominant pathogen. Significant counts have been made of coliforms, *Candida albiens* and *Pseudomonas*. In addition, waste mixtures have high concentrations of paper and cotton textiles that have proven ideal for the transmission of viruses. Other researchers have shown that *Escherichia coli* can contaminate hospital environments. Of the many fungi to be found in the environment, the systemic, or deep seated, mycoses create the most problems for humans. Many are airborne, entering through the respiratory tract, are found in hospital wastes, and can create allergens in hospital patients and staff.

The recorded biologically hazardous nature of hospital wastes indicate that the housekeeping practices used in collecting, transporting, centralizing, reducing, and moving these materials off-site must be excellent at all times. If there are breaks in management technique, the environment of patient and ancillary areas will be contaminated, with a good possibility of affecting the patients and staff.

In preparing the methodology for bacteriological testing, the survey team worked in close association with administrative, housekeeping, materials management, and maintenance staffs of the three survey hospitals. The laboratories were consulted as to the environmental testing performed in the past. All three hospitals have excellent laboratory facilities and personnel and all three institutions are knowledgeable on both the importance and the methods of testing for bacteriological levels in the hospital environment to prevent the spread of infections, bacteria, and viruses encountered in treating patients.

In embarking on bacteriological testing of a solid wasge management program, and the systems and equipment that are used in the program, it is important to understand how hospitals normally handle solid waste and exactly what are the main purposes of such testing.

As has been pointed out repeatedly in this Report, well-managed hospitals follow certain definite procedures in handling waste:

1. Whether "infectious" or not, the waste products are deposited into some sort of container that is lined with some sort of removable bag.
2. This deposit is made at the point of waste generation and normally as rapidly as the waste is generated.
3. The deposit is normally made with a "gentle" motion--a gravity drop into the open bag--by nurses, aides, technicians, doctors, etc., and without stuffing, shoving, and forcing the waste into the bag. This prevents the waste from being "stirred up" and hence inhibits the spread of aerosols in the area of the waste container.
4. When the bag holding the waste is reasonably full, it is removed from the waste container and normally is tied or sealed immediately to prevent spillage of the waste and/or the further spread of aerosols.
5. The encapsulated waste is then removed from the generation area, to the central collection point in the building, and eventually, in either a reduced or a whole form, off-site.

In short, the bagged waste collection systems used by most hospitals appear to have been well thought out and capable of preventing contamination of the hospital environment by the waste; assuming the personnel follow each procedure properly and bags of a proper construction are always used. Obviously the bags must be completely sealed and must be water- and air-proof to prevent any leaching of the encapsulated waste onto the surfaces with which the bags come in contact during the process.

All three of the survey hospitals were extremely conscious of the potential environmental effects to the institution from solid waste. All used the procedures of encapsulating it in containers (waste baskets, trash bins, etc.) lined with plastic bags at the immediate point of generation, of not overloading such containers and bags, and of carefully tying or sealing the bags before removing them from the containers to commence transporting them. All impressed upon the nurse aide, housekeeping, and materials management personnel the importance of these procedures and the potential hazards of a torn, ripped, or punctured bag during the collection and transport process; including the fact that bags could contain disposable needles and sharps that could puncture the sides or bottoms and cut or puncture the handler. In all observations made by the survey team, handling personnel always picked up the bags by the tied top and maneuvered them in this position. Literally hundreds of such bags of waste were followed by the survey team during the initial collection process in which they were picked up from a waste container. At that stage, various transport methods were used. Most bags were deposited in a cart and then either moved to a chute room and transported by the pneumatic tube method, or the cartload was moved from the floor by hand. Alternatively the bag was hand carried from the initial deposit container to the chute room and sent through the pneumatic system, or it was carried either directly or via a soiled utility room to a nearby hand cart for movement off the floor.

Environmental testing in connection with such a system has one main purpose: to determine whether any breaks are occurring in the system; as the result of human error; or of weaknesses in the bags, and the bagging and sealing methods; or from the waste content itself (such as sharp objects puncturing the bags and allowing waste to escape); or from the equipment used in transporting and reducing the waste.

Carts are used to transport waste to chute rooms, and in some hospitals from the collector boxes to the compactor, incinerator, or other reduction and off-site hauling equipment. Carts are also used to transport certain wastes from the floors that do not go through the pneumatic system. Hence the surfaces of the carts should be tested to determine their bacterial levels.

In the case of a pneumatic tube transport system, the configuration of the equipment indicates where breaks in the technique could occur. There are six main components that should be tested. First, the chute rooms are recipients of waste bags, and it should be determined whether the bacterial levels of the floors and walls of these rooms differ from the nearby rooms and corridors. Secondly, the chute loading stations have the waste bags dropped into them; the doors, sills, and loading hoppers should be tested. The vertical chutes and pneumatic tubes that carry the bagged waste and the collector boxes at the end of the line will probably have the highest counts in view of the possibilities of bag breakage in transit. The effluent air from the collector boxes goes to the fan room where, if there are filters, bacteria can be trapped, or can escape to the outside atmosphere, through the sound attenuator, possibly allowing some contamination to escape into the fan room itself, or remain within the equipment.

As the purpose of the present study was to determine the effect of the pneumatic tube system on the improvement of environmental conditions, bacteriological testing was limited to this system.

The survey team believed that the bacterial levels of the waste itself have been sufficiently documented by other researchers. It is apparent that such levels will be found in the waste from any hospital that is tested and will also be found in the hospital compactors as the result of rupturing the waste bags during compaction.

While no torn bags or loose waste were observed, the chute rooms and chute loading station, as well as the hand carts, were tested in all three hospitals for bacterial contamination; to determine whether the levels in and around this equipment exceeded the levels of the adjacent areas with their normal "people and material traffic." For a point of comparison, all the hospitals involved make routine checks on the floors and walls of the nursing units and ancillary departments.

As transport through the pneumatic tube system was the next step in the operation for from 35 percent to 85 percent of the volume of the waste in each hospital, and as visual inspection had revealed considerable bag breakage when the bags dropped from the collector boxes at the end of the line, bacterial levels were then recorded within the tube and within the collector box at each hospital, as well as in the room holding the collector box (and the compactor).

As it was observed that the majority of bags were torn by the action of the compactor, it was obvious that readings would be quite high within this unit if bacteria were present in the waste. No readings were taken of the interior surfaces of the compactor. Concentration was instead on the area outside the collector box and compactor to determine leakage and the efficiency of the linkage between these two units.

To record the quality of the transport air, readings were taken of the filters adjacent to the exhaust fans and within the sound attenuator or exhaust duct after the fan, as well as within each of the fan rooms.

An interesting sidelight, in embarking on a program of bacteriological testing of a pneumatic transport system is the firm conviction on the part of many of the staff that, despite all they have observed in the way of careful methods used in waste handling, the results from testing of the pneumatic system will be colonies that are "T.N.T.C." (too numerous to count). This is a general psychological reaction to solid waste. Experienced waste handlers know they are dealing with a dangerous substance that has the capacity to sicken or even kill its handlers. It is also a reaction to the tube system and to a degree a lack of trust in its efficiency to safely transport encapsulated bags of waste. Too many handlers have observed ruptured bags emerge from the collector boxes. Maintenance crews are particularly convinced that the elements of the pneumatic system present one of the most dangerous environments with which they must work. Instances were given the research team of maintenance men developing skin rashes and other afflictions that they claimed resulted from working on the pneumatic system. Unfortunately it was impossible to verify any connection from the available records.

To properly evaluate the efficiency of a pneumatic tube waste management system and in encapsulating solid waste, two types of readings were required.

1. Surface sampling--Swab and RODAC samples from the surface areas of

the equipment, such as the hand carts for moving the waste; and the sills, frames, doors, tubes, collector boxes, filters, and fan room equipment of the pneumatic tube system.

2. Air sampling--To record the spread of aerosols in the chute loading rooms, the collector-compactor rooms, and the fan equipment rooms.

As the greatest activity occurred in each hospital between 8:00 a.m. and 3:00 p.m., samples were collected during this peak period. They were taken to the laboratory immediately after collection and the interval between sampling and analysis did not exceed three to four hours.

Tryptose Glucose Yeast Agar (DIFCO) (Standard Methods Agar) was used as a general plating medium for enumeration of bacterial populations and an indicator of the general level of contamination.

Tellurite Glycine Agar (BBL) was used for the quantitative detection of coagulose-positive staphylococci. Selective inhibition is attained by means of lithium chloride, tellurite and glycine; pathogenic coagulose-positive cocci form black colonies on the surface within 24 to 48 hours which can be counted easily.

MacConkey Agar (BBL) was used for the detection of *Escherichia coli*; a bile salt mixture is used for inhibitions of gram-positive organisms.

Cooke Rose Bengal Agar (DIFCO) was used as a selective medium for the isolation of fungi; selectivity is obtained by the dye, rose bengal, and two antibiotics, penicillin and streptomycin.

For sampling, a one percent peptone phosphate buffer solution was used as a dilution fluid to preserve microbes.

The principal specific bacteria for which samples were taken and cultures made were *Staphylococcus aureus*, *Streptococcus faecalis*, *Pseudomonas aeruginosa*, *Bacillus subtilis*, and *Escherichia coli*. In addition, effort was made to determine the incidence of saprophytic bacteria in general and of fungi on the equipment and the waste management areas.

VETERANS ADMINISTRATION HOSPITAL

The personnel of the Veterans Administration Hospital are acutely aware of the potentially deleterious effects upon the hospital environment from the hospital's solid wastes. All levels of hospital administration--from top management, through department director level, through section head level, and in the various laboratories--are actively interested in whether contamination from solid waste is affecting patients, staff, or visitors. In particular, they are interested in whether the pneumatic solid waste transport system is or is not contributing to surface or air contamination. Equally, they are interested in whether this pneumatic system is superior to the system of hand hauling solid waste with respect to the spread of bacteriological contamination.

Certain staff personnel of this hospital have been accustomed to routinely performing periodic bacteriological testing to determine the level of contamination at various points in the hospital. Recent manpower shortages in the laboratories, however, have limited their capabilities to perform as many of these tests as they would like. Despite laboratory manpower shortages, the testing program was welcomed and given complete cooperation by the hospital administrative staff.

Microorganisms of particular interest were staphylococcus aureus, pseudomonas aeruginosa, and klebsiella. Information on other bacteria which might be present was also desired, even though these bacteria might be nonpathogenic.

The survey team felt that a minimum of one half of the chute loading stations should be tested in order to assure a reliable and representative testing of the system. These should be those receiving the highest use factor. The following stations were selected:

1E	2E	5E
2S	4S	6S
3N	4N	5N
	3W	

Test samples were also taken inside one half of the trash carts and one half of the soiled linen carts; in the trash and linen collectors; inside the incinerator room; inside the compactor room; in the compactor loading hopper; in the fan room; and adjacent to the effluent air filter.

The results have not uncovered the presence of any pathogenic fomites or air contamination inside the hospital attributable to the pneumatic tube system. Non-pathogenic organisms likewise have not been uncovered to a significant level.

MARTIN LUTHER KING HOSPITAL

This hospital also has a staff extremely conscious of the potential environmental effects to the institution of solid waste. Here again, the survey team found from personal discussions that all echelons from top management down to working staff were aware of the hazards that might arise from the problems of solid waste disposal. Although this attitude was generally held in all areas, it was particularly noticeable among the microbiology laboratory staff.

The hospital routinely and regularly conducts their own microbiological testing throughout the institution. This routine testing, done by the hospital staff, has normally been undertaken to determine the general level of airborne cross-contamination that might be present inside the hospital. The staff expressed great interest to the survey team, however, in conducting tests to determine whether or not any contamination which might be present could be attributed to the pneumatic solid waste transport system, and how the hand hauled cart system might compare to this.

The microorganisms of particular interest were staphylococcus aureus, pseudomonias aeruginosa, and klebsiella. Information on other bacteria present was also sought.

The team felt that a minimum of one half the chute loading stations should be included in the survey in order to assure a representative sample. The following stations were selected:

Segment I, 1st floor
Segment I, 2nd floor
Segment I, 3rd floor
Segment I, 5th floor
Wing A, 1st floor
Wing A, 2nd floor
Wing A, 3rd floor
Wing B, 3rd floor
Wing B, 4th floor
Wing C, 2nd floor
Wing C, 4th floor

Test samples were also to be taken inside one half of the trash carts and one half the soiled linen carts; in the trash and linen collectors; inside the incinerator room; inside the compactor room; in the compactor loading hopper; in the fan and filter room; and adjacent to the effluent air filter.

The results have not uncovered the presence of any pathogens such as staph aureas or pseudomonas anywhere in the hospital that might be attributable to the pneumatic tube system. Traces of klebsiella, however, were found on the laundry floor. There were fewer than five colonies, which is not considered a significant concentration. Klebsiella is an organism which in concentrations of approximately 40 colonies or above can cause throat and nose infections, intestinal infections, sepsis in the bloodstream, and meningitis.

Several non-pathogens were identified. These included staphylococcus epidermis, diphtheroids, and bacillus subtilis. The face of all slide valves, both trash and linen, and the floor near the compactor, had colonies of these non-pathogens, which were too numerous to count. None of these were considered significant, being non-pathogens.

ST. MARY'S HOSPITAL

This hospital is also acutely aware of the need for excellent housekeeping and of the potentially dangerous effects upon the hospital environment that could be attributed to the handling of solid waste. It was found, after conducting several personal interviews, that top management was interested not only in good housekeeping practices but also in whether contamination from solid waste was affecting patients, staff, or visitors. There was interest in whether either the pneumatic tube system or the hand hauled waste system could contribute to surface or air contamination in the hospital. Extensive laboratory testing in the past did not appear to have been carried out frequently on a regular basis on these particular elements.

Here again, the microorganisms of particular interest were *staphylococcus aureus*, *pseudomonas aeruginosa*, and *klebsiella*. Information on other bacteria present was also desired, even though they might be non-pathogens.

The following chute loading stations were selected for testing:

3 East
4 East
5 East
4 Center
5 Center
6 Center
7 Center
2 West
4 West
8 West

Test samples were also taken inside one half the trash and linen carts; in the trash and linen collectors; inside the incinerator room; in the compactor loading hopper; and adjacent to the effluent air ducts.

No pathogenic bacteria were identified in any of the locations. Non-pathogenic bacteria such as *staphylococcus epidermis* and *diphtheroids* and *bacillus subtilis* were identified. The highest colony count of any of these non-pathogens was 13, which occurred in trash chute 2 West.

REPORT OF BACTERIOLOGICAL TESTING

ST. MARY'S HOSPITAL

AREA TAKEN FROM	C - S - P	TYPE OF SWAB SAMPLE
Trash chute/1-C	1 - 0 - 0	dry
Trash chute/1-W	0 - 0 - 0	dry
Trash chute/3-E	0 - 0 - 0	dry
Trash chute/2-E	0 - 0 - 0	dry
Trash chute/3-C	1 - 0 - 0	dry
Trash chute/3-W	13 - 0 - 0	dry
Trash chute/2-W	0 - 0 - 0	dry
Trash chute/O.R.	0 - 0 - 0	dry
Trash chute/5-E	5 - 0 - 0	dry
Trash cart/incinerator room	0 - 0 - 0	dry
Trash hopper/incinerator room	0 - 0 - 0	dry
Linen hopper/laundry	0 - 0 - 0	dry
Trash cart/incinerator room	0 - 0 - 0	dry
Trash hopper/incinerator room	0 - 0 - 0	dry
Linen hopper/laundry	0 - 0 - 0	dry
Linen chute/2-W	1 - 0 - 0	dry
Linen chute/3-E	1 - 0 - 0	dry
Linen chute/3-W	0 - 0 - 0	dry
Trash cart/incinerator room	0 - 0 - 0	wet
Trash hopper/incinerator room	0 - 0 - 0	wet
Trash cart/incinerator room	0 - 0 - 0	wet
Trash hopper/incinerator room	0 - 0 - 0	wet
Linen hopper/laundry	0 - 0 - 0	wet

C - Colonies
S - Staph aureus
P - Pseudomonas

Methodology: Swab samples streaked on mannitol salt agar for detection of staphylococcus aureus and on MacConkey's agar for pseudomonas. All were incubated at 37°C. for 48 hours.

10-ECONOMICS OF HOSPITAL WASTE MANAGEMENT

The transporting and reduction of hospital solid waste has become increasingly costly during the past fifteen years as the volume of waste has increased along with hourly cost of the labor and supplies that must manage it. With labor representing as high as 80 percent of the average hospital's operating budget, every effort is made to conserve wages. Automation and mechanization, by the installing of methods such as pneumatic transport systems, has been one approach hospitals have used.

Most hospitals are now approaching capital expenditures on the basis that they must save enough labor for such capital outlays to be self-liquidating in under a ten year period. In the case of solid waste transport systems this is an extremely difficult goal to achieve due to a variety of factors, ranging from high capital installed costs, to cost of supplies, maintenance, power and utility requirements, to the feasibility of using the automated system to the maximum degree for the waste that must be transported as against hand cart or other methods.

CAPITAL COSTS OF THE TRANSPORT SYSTEM

In evaluating the costs of an automated installation such as a solid waste pneumatic transport system, the amount of space taken up in the building by all the components of the system and the value of the space, coupled with the installed price of the equipment, and the installed cost of all utilities that are necessary for the operation of the system, are the principal factors. Based on the original construction records these costs were obtained from the architect for each of the three pilot study hospitals. Space required for waste handling external to the pneumatic tube system, yet exclusively devoted to this purpose also must be included, such as chute loading rooms, waste storage areas, compactor and incinerator areas. To this must be added the cost of the money for purchasing the space and equipment; the interest on investment that will be incurred over the expected life of the system. In developing costs, the space used and the pneumatic system were capitalized as an investment over a twenty year period.

It is extremely difficult to obtain completely accurate figures in the capital cost between the equipment itself and the labor required to install it. A reasonable rule of thumb appears to be that, in the final installed price, installation labor represents approximately 60 percent of the total.

CAPITAL COSTS OF INTERFACED EQUIPMENT

In a complete analysis of a solid waste pneumatic transport system it is important to also investigate the costs of all other equipment that interfaces with the tube system. These items fall into two general classifications. (1) Accessory equipment that is necessary to ensure the successful operation of the transport system: such as carts to move the waste to the chute doors and away from the final collector; or conveyors or other devices that will move waste from remote points to provide a mechanical interface with the pneumatic system; and reduction equipment such as floor compactors and shredders or grinders to ensure waste will fit into the chutes. (2) General waste handling equipment that is independent of the transport system but provides further efficiency in solving the overall problem: such as compactors, attrition mills, incinerators and gas scrubbers, trucks, scales, lifts, balers, conveyors, and off-site hauling vehicles and containers. Finally, for the waste that is not handled by the pneumatic transport system there are the capital costs of elevators and other similar items, a portion of which are used for the transport of waste at various times of the day.

In the three pilot hospitals, equipment on the floors that interfaced with the pneumatic system were hand carts which were used to haul waste to chute loading rooms and also to move bulky waste from the floors to the central collection point. All of the hospitals had reduction equipment installed (compactor and incinerator) after the final collector of the pneumatic system. All of the hospitals were high rise structures and used elevators. In developing waste management costs such equipment was not capitalized, as it can be purchased separately from the structure. A straight line depreciation method was used, extending over the expected equipment life.

OPERATING COSTS OF THE PNEUMATIC SYSTEM

The principal operating cost is labor. The first element is for materials handling: the hours required to haul waste from the various points of generation to the chute loading doors; depositing waste in the chutes (including waiting times); moving waste from the collector at the end of the line to reduction units such as compactor or incinerator. The second element is labor for maintenance, both corrective and preventive. The third element is slightly different, yet similar, to maintenance; namely housekeeping labor required to keep the system and its interfacing areas clean and presentable. The fourth element is the cost of training all labor elements in the operation of the system as well as directly managing the people who are actually doing the work. To these direct labor costs must be added the fringe benefits and other labor overhead elements.

The second heaviest operating cost involves the supplies in which waste is stored and transported, namely the various disposable bags and closures. Thirdly are the costs of utilities, such as power to run the system.

OPERATING COSTS OF INTERFACED SYSTEMS

As seen from the preceding chapters, the pneumatic system handles only a percentage of the total waste of each institution. The balance is hand-hauled by cart to the central collection point. The labor for this has been separated from the labor used for the pneumatic system.

The next major element in this group is that labor required to load and maintain the reduction equipment at the end of the line, such as compactor and incinerator, and to ensure that the housekeeping of this equipment, and the area in which it is installed, is satisfactory.

The additional supplies for the interfaced equipment consist primarily of the bags required to contain the hand-hauled waste and the cleaning materials required for the reduction areas.

The utility costs of power for the compactor and incinerator, gas and oil for the latter are the next item to be included. The final cost at the end of the line is the contract for hauling the waste off-site to the landfill. (This applied at each of the three hospitals.)

A final item that must be included in determining the total waste management costs for an institution is the cost of all the storage containers throughout the floors of the building, ranging from waste baskets to 44 gallon containers, amortized over their expected life.

DIVISION OF FIXED COSTS BETWEEN WASTE AND LAUNDRY TRANSPORT

It could be argued that the entire fixed charges of installed equipment and space costs, maintenance labor, and utility costs for a pneumatic system could be charged against either waste or laundry transport, on the basis that any hospital could elect to remove either product from using the system at some point in time. (A review of all hospitals with pneumatic systems has revealed that this has happened in a few cases due to management decisions.)

However, when the systems were originally installed for transporting both products, as in the case of the three hospitals in the present study, it is more logical to divide these fixed system costs between waste and laundry transport. This approach has been used in this chapter and the following one to determine the economic feasibility of a pneumatic transport system. The basis for the calculation is the number of bags of each product (rather than weight or cube) that travel the system, as individual bag loads more closely represent the true use factor of such a system.

Tables 22 through 45 analyze all the foregoing cost factors for each of the three hospitals studied and compare financially the systems each is using.

TABLE 22

COST ANALYSIS

ST. MARY'S HOSPITAL, DULUTH

PNEUMATIC SOLID WASTE TRANSPORT SYSTEM

CAPITAL COSTS

Building Costs

Total Construction Costs	Total Square Feet	Cost/ Square Foot	Total Cubic Feet	Cost/ Cubic Foot
$24,386,090	518,853	$47.00	7,902,910	$3.09

1. Area Costs

	Square Feet	Value @ $47.00	Total
Laundry collector	576	$ 27,072	
Waste collector	216	10,152	
Fan room	265	12,455	
Control panel	150	7,050	
Load stations (chute rooms), total	1,008	47,376	
Totals	2,215	$104,105	$104,105

2. Volume Costs

	Length, Ft.	Volume @ 16"D	Value @ $3.09	
Linen, waste & air tubes	1,700	2,363	$7,302	
Totals	1,700	2,363	$7,302	$ 7,302

3. Cost of Pneumatic System - Equipment and Installation	$193,157
TOTAL CAPITAL INVESTMENT FOR SPACE AND SYSTEM	$304,564
TOTAL CAPITAL COST PER YEAR, 7% INTEREST, 20-YEAR LIFE	$ 36,548

TABLE 23

COST ANALYSIS

ST. MARY'S HOSPITAL, DULUTH

PNEUMATIC SOLID WASTE TRANSPORT SYSTEM

DIRECT COSTS

1. Labor	Avg. Rate w/Fringes	Avg. Hrs./ Month	Avg. Cost/ Month	Hrs./ Year	Cost/ Year	Total Dollars
Haul to and load chutes	$2.66	441	$1,173	5,292	$14,077	
Move to and load compactor	2.86	74	212	888	2,540	
Maintenance, corrective and preventive	4.95	59	292	708	3,505	
Total Labor Costs		574	$1,677	6,888	$20,122	$20,122

2. Bags to Transport Waste	No./ Month	Cost/ Month	No./ Year	Cost/ Year	
Black plastic	7,000	$ 400	84,000	$ 4,800	
Nylon mesh	4,410*	873	52,900	10,476	
Total Supplies Cost		$1,273		$15,276	$15,276

3. Total Utilities (Power & Control)	Cost/Month	Cost/Year	
	$510	$6,121	$ 6,121
TOTAL DIRECT COSTS			$41,519

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* These are reusable transport bags in which the plastic waste bags are placed to prevent breakage or bag ripping. Each nylon bag is used for one transport, then emptied, laundered, and re-issued. Total average inventory is approximately 600. Average life is 200 uses. Cost for each use: to purchase, fill, handle, dump, launder, store, and re-issue = $0.198 each per day.

TABLE 24

COST ANALYSIS

ST. MARY'S HOSPITAL, DULUTH

PNEUMATIC SOLID WASTE TRANSPORT SYSTEM

SUMMARY OF ANNUAL COSTS

CAPITAL COSTS AMORTIZED:		$36,548
DIRECT OPERATING COSTS:		
Labor	$20,122	
Transport Bags	15,276	
Utilities	6,121	
Total		$41,519
INDIRECT OPERATING COSTS:		
Downtime		$ 255
TOTAL COST PER YEAR:		$78,322
TOTAL COST PER MONTH:		$ 6,527
DEDUCTION OF FIXED CHARGES PER YEAR ASSIGNED TO LAUNDRY TRANSPORT (80%):		
Capital Costs	$29,238	
Utilities Costs	4,897	
Maintenance Costs	2,804	
Total Deductions		$36,939
NET COST PER YEAR FOR WASTE TRANSPORT:		$41,383
NET COST PER MONTH FOR WASTE TRANSPORT:		$ 3,449

COST ANALYSIS

ST. MARY'S HOSPITAL, DULUTH

PNEUMATIC SOLID WASTE TRANSPORT SYSTEM

(Continued)

Total Pounds Transported per Month:	26,733
Total Cost per Pound of Solid Waste Transported:	$ 0.13
Total Cubic Feet Transported per Month:	11,578
Total Cost per Cubic Foot of Solid Waste Transported:	$ 0.30
Total Bags Transported per Month:	4,456
Total Cost per Bag of Solid Waste Transported:	$ 0.77

TABLE 25
COST ANALYSIS
ST. MARY'S HOSPITAL, DULUTH
HAND HAULED SOLID WASTE TRANSPORT SYSTEM

Labor

	Cost/Hr.	Hrs./Mo.	Cost/Mo.	Hrs./Yr.	Cost/Yr.	Totals
Pick up bags, load cart, walk to elevator	$2.93	311	$ 911	3,732	$10,935	
Elevator time, including waiting, loading, and unloading	2.93	68	199	816	2,391	
Walk from elevator & unload	2.93	10	29	120	352	
Total Labor Costs		389	$1,139	4,668	$13,678	$13,678

Bags to Receive and Transport Waste

	No./Month	Cost/Month	No./Year	Cost/Year	Totals
Beige plastic	20,000	$ 240	240,000	$ 2,880	
Clear plastic	10,000	345	120,000	4,140	
Red plastic	1,600	84	19,200	1,008	
Clear kick bucket	1,600	53	19,200	639	
Clear poly	5,000	286	60,000	3,432	
Total Supplies Cost		$1,008		$12,099	$12,099

Utilities

	Cost/Month	Cost/Year	
Elevator power 25HP x 0.746 x $0.015 x 4.5 hrs./day x 7 x 4.33	$38	$456	$ 456

COST ANALYSIS

ST. MARY'S HOSPITAL, DULUTH

HAND HAULED SOLID WASTE TRANSPORT SYSTEM

(Continued)

Depreciation of Equipment

	Cost/Month	Cost/Year	
Elevator, @ $60,000, 25-year life, used 20% of the time	$ 40	$ 480	
Waste baskets, trash containers @ $3.50, 5-year life	73	880	
Carts, 2 @ $200, 10-year life,	3	40	
Total Depreciation Costs	$116	$1,400	$ 1,400

TABLE 26

COST ANALYSIS

ST. MARY'S HOSPITAL, DULUTH

HAND HAULED SOLID WASTE TRANSPORT SYSTEM

SUMMARY OF ANNUAL COSTS

Labor	$13,678
Transport Bags	12,099
Utilities	456
Depreciation	1,400
TOTAL COST PER YEAR:	$27,633
TOTAL COST PER MONTH:	$ 2,303
Total Pounds Transported per Month:	42,161
Cost per Pound of Solid Waste Transported:	$ 0.06
Total Cubic Feet Transported per Month:	5,607
Cost per Cubic Foot of Solid Waste Transported:	$ 0.41
Total Cart Trips per Month:	455
Cost per Cart Load of Solid Waste:	$ 5
Cost per Bag Equivalent:	$ 0.32

TABLE 27

COST ANALYSIS

ST. MARY'S HOSPITAL, DULUTH

END OF LINE SOLID WASTE HANDLING

Labor	Avg. Rate w/Fringes	Avg. Hrs./ Month	Avg. Cost/ Month	Hrs./ Year	Cost/ Year	Total Dollars
Load incinerator	$2.93	30	$ 88	360	$1,055	
Incinerator ash removal	2.93	38	111	456	1,336	
Clean compactor and bin		(none - done by contractor)				
Clean compactor and incinerator areas	2.93	20	59	240	703	
Maintenance, compactor and incinerator	2.93	12	35	144	422	
Total Labor Costs		100	$293	1,200	$3,516	$ 3,516
Off-Site Hauling						
2 times per week @ $44			$381		$4,572	
Cleaning			15		176	
Total Hauling Costs			$396		$4,748	$ 4,748
Amortization of Space						
Incinerator room, 20-year life, 162 sq. ft. @ $47			$ 76		$ 914	
Loading dock, 20-year life			$ 76		914	
Total Amortization Costs			$152		$1,828	$ 1,828
Depreciation of Equipment						
Incinerator, 10-year life			$283		$3,400	
Compactor, 10-year life			42		509	
Total Depreciation Costs			$325		$3,909	$ 3,909

COST ANALYSIS

ST. MARY'S HOSPITAL, DULUTH

END OF LINE SOLID WASTE HANDLING

(Continued)

Utilities	Avg. Cost/ Month	Cost/ Year	Total Dollars
Incinerator	$ 11	$ 132	
Compactor	1	12	
Total Utilities Costs	$ 12	$ 144	$ 144

TABLE 28

COST ANALYSIS

ST. MARY'S HOSPITAL, DULUTH

END OF LINE SOLID WASTE HANDLING

SUMMARY OF ANNUAL COSTS

Labor	$ 3,516
Off-Site Hauling	4,748
Space	1,828
Equipment	3,909
Utilities	144
TOTAL COST PER YEAR	$14,145
TOTAL COST PER MONTH	$ 1,179
Total Incoming Pounds Handled per Month:	68,894
Cost per Incoming Pound Handled:	$ 0.02
Total Incoming Cubic Feet Handled per Month:	17,185
Cost per Incoming Cubic Foot Handled:	$ 0.07
Total Bags and Bag Equivalents Handled per Month:	11,736
Cost per Bag and Equivalent:	$ 0.10

TABLE 29

COST ANALYSIS

ST. MARY'S HOSPITAL, DULUTH

SUMMARY OF TOTAL HOSPITAL SOLID WASTE COSTS

			Per Annum
1.	Labor:		
	Pneumatic System	$20,122	
	Hand Hauled System	13,678	
	End of Line System	3,516	
	Total	$37,316	
	Less Laundry % of P/N Maintenance (80%)	2,804	
	Net Labor Cost		$34,512
2.	Transport Bags:		
	Pneumatic System	$15,276	
	Hand Hauled System	12,099	
	Total Transport Bag Cost		$27,375
3.	Capital Costs:		
	P/N System & Space	$36,548	
	End of Line Space	1,828	
	Total	$38,376	
	Less Laundry % of P/N Capital (80%)	29,238	
	Net Capital Cost		$ 9,138
4.	Depreciation of Equipment:		
	Hand Hauled System	$ 1,400	
	End of Line System	3,909	
	Total Depreciation		$ 5,309
5.	Off-Site Hauling Contract:		$ 4,748

COST ANALYSIS

ST. MARY'S HOSPITAL, DULUTH

SUMMARY OF TOTAL HOSPITAL SOLID WASTE COSTS

(Continued)

		Per Annum
6. **Utilities:**		
Pneumatic System	$ 6,121	
Hand Hauled System	456	
End of Line System	144	
Total	$ 6,721	
Less Laundry % of P/N Utilities (80%)	4,897	
Net Utilities Cost		$ 1,824
7. Indirect Costs - Downtime of P/N System:		$ 255
TOTAL NET COST PER YEAR:		$83,161
TOTAL NET COST PER MONTH:		$ 6,930
Total Pounds Disposed per Month:		68,894
Net Cost per Pound Disposed:		$ 0.10
Total Cubic Feet Disposed per Month:		17,185
Net Cost per Cubic Foot Disposed:		$ 0.40
Total Bags and Bag Equivalents per Month:		11,736
Net Cost per Bag and Equivalent:		$ 0.59
Percent of Total Net Cost Attributable to Pneumatic System:		58%
Percent of Total Net Cost Attributable to Hand Hauling:		42%

TABLE 30

COST ANALYSIS

VETERANS ADMINISTRATION HOSPITAL, SAN DIEGO

PNEUMATIC SOLID WASTE TRANSPORT SYSTEM

CAPITAL COSTS

Building Costs

Total Construction Costs	Total Square Feet	Cost/ Square Foot	Total Cubic Feet	Cost/ Cubic Foot
$35,250,000	677,700	$52.01	14,645,165	$2.41

1. Area Costs

	Square Feet	Value @ $52.01	Total
Laundry collector	63	$ 3,277	
Waste collector & compactor	578	30,062	
Fan room	465	24,185	
Control panel	156	8,114	
Load stations (chute rooms), total	3,238	168,408	
Totals	4,500	$234,046	$234,046

2. Volume Costs

	Length, Ft.	Volume @ 16"D	Value @ $2.41	
Linen & waste tube	1,303	1,818	$4,381	
Air tube	591	825	1,988	
Totals	1,894	2,643	$6,369	$ 6,369

3. Cost of Pneumatic System - Equipment and Installation	$350,000
TOTAL CAPITAL INVESTMENT FOR SPACE AND SYSTEM	$590,415
TOTAL CAPITAL COST PER YEAR, 7% INTEREST, 20-YEAR LIFE	$ 70,850

TABLE 31

COST ANALYSIS

VETERANS ADMINISTRATION HOSPITAL, SAN DIEGO

PNEUMATIC SOLID WASTE TRANSPORT SYSTEM

DIRECT COSTS

1. Labor	Avg. Rate w/Fringes	Avg. Hrs./ Month	Avg. Cost/ Month	Hrs./ Year	Cost/ Year	Total Dollars
Haul to chute loading room	$3.31	319	$1,056	3,828	$12,671	
Load chutes	3.66	143	523	1,716	6,281	
Load compactor		(no cost - automatic loading)				
Maintenance, corrective and preventive	4.92	38	187	454	2,224	
Total Labor Costs		500	$1,766	5,998	$21,186	$21,186

2. Bags to Transport Waste	No./ Month	Cost/ Month	No./ Year	Cost/ Year	
White plastic	9,700	$237	116,400	$2,849	
Total Supplies Cost		$237		$2,849	$ 2,849

3. Total Utilities (Power & Control)	Cost/Month	Cost/Year	
	$560	$6,721	$ 6,721

TOTAL DIRECT COSTS	$30,756

TABLE 32

COST ANALYSIS

VETERANS ADMINISTRATION HOSPITAL, SAN DIEGO

PNEUMATIC SOLID WASTE TRANSPORT SYSTEM

SUMMARY OF ANNUAL COSTS

CAPITAL COSTS AMORTIZED:		$ 70,850
DIRECT OPERATING COSTS:		
Labor	$21,186	
Transport Bags	2,849	
Utilities	6,721	
Total		$ 30,756
INDIRECT OPERATING COSTS:		
Downtime		$ 2,112
TOTAL COST PER YEAR:		$103,718
TOTAL COST PER MONTH:		$ 8,643
DEDUCTION OF FIXED CHARGES PER YEAR ASSIGNED TO LAUNDRY TRANSPORT (54%):		
Capital Costs	$38,259	
Utilities Costs	3,629	
Maintenance Costs	1,201	
Total Deductions		$ 43,089
NET COST PER YEAR FOR WASTE TRANSPORT:		$ 60,629
NET COST PER MONTH FOR WASTE TRANSPORT:		$ 5,052

COST ANALYSIS
VETERANS ADMINISTRATION HOSPITAL, SAN DIEGO
PNEUMATIC SOLID WASTE TRANSPORT SYSTEM
(Continued)

Total Pounds Transported per Month:		33,796
Total Cost per Pound of Solid Waste Transported:	$	0.15
Total Cubic Feet Transported per Month:		16,701
Total Cost per Cubic Foot of Solid Waste Transported:	$	0.30
Total Bags Transported per Month:		9,578
Total Cost per Bag of Solid Waste Transported:	$	0.53

TABLE 33

COST ANALYSIS

VETERANS ADMINISTRATION HOSPITAL, SAN DIEGO

HAND HAULED SOLID WASTE TRANSPORT SYSTEM

Labor

	Cost/Hr.	Hrs./Mo.	Cost/Mo.	Hrs./Yr.	Cost/Yr.	Totals
Pick up bags, load cart, walk to elevator	$3.66	114	$417	1,368	$5,007	
Elevator time, including waiting, loading, and unloading	3.66	24	88	288	1,054	
Walk from elevator & unload	3.66	5	18	60	220	
Total Labor Costs		143	$523	1,716	$6,281	$ 6,281

Bags to Receive and Transport Waste

	No./Month	Cost/Month	No./Year	Cost/Year	
Clear waste liner	36,000	$ 803	432,000	$ 9,635	
Small red	6,500	339	78,000	4,064	
Large red	4,400	394	52,800	4,726	
Small yellow	1,000	38	12,000	459	
Large yellow	1,000	57	12,000	688	
Large vinyl	3,300	248	39,600	2,970	
Surgery, non-static	620	46	7,440	555	
Total Supplies Costs		$1,925		$23,100	$23,100

Utilities

	Cost/Month	Cost/Year	
Elevator power, 25HP x 0.746 x $0.015 x 12 hrs./day x 7 x 4.33	$103	$1,236	$ 1,236

COST ANALYSIS

VETERANS ADMINISTRATION HOSPITAL, SAN DIEGO

HAND HAULED SOLID WASTE TRANSPORT SYSTEM

(Continued)

Depreciation of Equipment

	Cost/Month	Cost/Year	
Elevator, @ $60,000, 25-year life, used 50% of the time	$100	$1,200	
Carts,			
2 rubber @ $200	3	40	
2 O.R. aluminum @ $300 10-year life	5	60	
Waste baskets, trash containers @ $3.50, 5-year life	211	2,530	
Total Depreciation Costs	$319	$3,830	$ 3,830

TABLE 34

COST ANALYSIS

VETERANS ADMINISTRATION HOSPITAL, SAN DIEGO

HAND HAULED SOLID WASTE TRANSPORT SYSTEM

SUMMARY OF ANNUAL COSTS

Labor	$ 6,281
Transport Bags	23,100
Utilities	1,236
Depreciation	3,830
TOTAL COST PER YEAR:	$ 34,447
TOTAL COST PER MONTH:	$ 2,871
Total Pounds Transported per Month:	100,932
Cost per Pound of Solid Waste Transported:	$ 0.03
Total Cubic Feet Transported per Month:	30,856
Cost per Cubic Foot of Solid Waste Transported:	$ 0.09
Total Cart Trips per Month:	940
Cost per Cart Load of Solid Waste:	$ 3.05
Cost per Bag Equivalent:	$ 0.19

TABLE 35

COST ANALYSIS

VETERANS ADMINISTRATION HOSPITAL, SAN DIEGO

END OF LINE SOLID WASTE HANDLING

Labor	Avg. Rate w/Fringes	Avg. Hrs./ Month	Avg. Cost/ Month	Hrs./ Year	Cost/ Year	Total Dollars
Load incinerator	$3.66	65	$238	780	$2,855	
Incinerator ash removal	3.66	40	146	480	1,757	
Clean compactor and bin	3.66	47	172	564	2,064	
Clean compactor and incinerator areas	3.66	28	102	336	1,230	
Maintenance, compactor and incinerator	3.66	13	48	156	571	
Total Labor Costs		193	$706	2,316	$8,477	$ 8,477
Off-Site Hauling						
3 times per week @ $80			$1,045		$12,562	
Cleaning	(Done in-house. Included in labor, above.)					
Total Hauling Costs			$1,045		$12,562	$12,562
Amortization of Space						
Incinerator room, 20-year life, 903 sq. ft. @ $52			$470		$5,636	
Loading dock, 200 sq. ft. @ $52			104		1,248	
Total Amortization Costs			$574		$6,884	$ 6,884
Depreciation of Equipment						
Incinerator, 10-year life			$595		$7,140	
Compactor & 2 bins, 10-year life			58		700	
Total Depreciation Costs			$653		$7,840	

COST ANALYSIS

VETERANS ADMINISTRATION HOSPITAL, SAN DIEGO

END OF LINE SOLID WASTE HANDLING

(Continued)

Utilities	Avg. Cost/ Month	Cost/ Year	Total Dollars
Incinerator	$16	$192	
Compactor	4	48	
Total Utilities Costs	$20	$240	$ 240

TABLE 36

COST ANALYSIS

VETERANS ADMINISTRATION HOSPITAL, SAN DIEGO

END OF LINE SOLID WASTE HANDLING

SUMMARY OF ANNUAL COSTS

Labor	$ 8,477
Off-Site Hauling	12,562
Space	6,884
Equipment	7,840
Utilities	240
TOTAL COST PER YEAR	$ 36,003
TOTAL COST PER MONTH	$ 3,000
Total Incoming Pounds Handled per Month:	134,728
Cost per Incoming Pound Handled:	$ 0.02
Total Incoming Cubic Feet Handled per Month:	47,557
Cost per Incoming Cubic Foot Handled:	$ 0.06
Total Bags and Bag Equivalents Handled per Month:	24,618
Cost per Bag and Equivalent:	$ 0.12

TABLE 37

COST ANALYSIS

VETERANS ADMINISTRATION HOSPITAL, SAN DIEGO

SUMMARY OF TOTAL HOSPITAL SOLID WASTE COSTS

			Per Annum
1.	Labor:		
	Pneumatic System	$21,186	
	Hand Hauled System	6,281	
	End of Line System	8,477	
	Total	$35,944	
	Less Laundry % of P/N Maintenance (54%)	1,201	
	Net Labor Cost		$ 34,743
2.	Transport Bags:		
	Pneumatic System	$ 2,849	
	Hand Hauled System	23,100	
	Total Transport Bag Cost		$ 25,949
3.	Capital Costs:		
	P/N System & Space	$70,850	
	End of Line Space	6,884	
	Total	$77,734	
	Less Laundry % of P/N Capital (54%)	38,259	
	Net Capital Cost		$ 39,475
4	Depreciation of Equipment:		
	Hand Hauled System	$ 3,830	
	End of Line System	7,840	
	Total Depreciation		$ 11,670
5.	Off-Site Hauling Contract:		$ 12,562

COST ANALYSIS
VETERANS ADMINISTRATION HOSPITAL, SAN DIEGO
SUMMARY OF TOTAL HOSPITAL SOLID WASTE COSTS
(Continued)

		Per Annum
6. Utilities:		
Pneumatic System	$ 6,721	
Hand Hauled System	1,236	
End of Line System	240	
Total	$ 8,197	
Less Laundry % of P/N Utilities (54%)	3,629	
Net Utilities Cost		$ 4,568
7. Indirect Costs - Downtime of P/N System:		$ 255
TOTAL NET COST PER YEAR:		$129,222
TOTAL NET COST PER MONTH:		$ 10,768
Total Pounds Disposed per Month:		134,728
Net Cost per Pound Disposed:		$ 0.08
Total Cubic Feet Disposed per Month:		47,557
Net Cost per Cubic Foot Disposed:		$ 0.23
Total Bags and Bag Equivalents:		24,618
Net Cost per Bag and Equivalent:		0.44
Percent of Total Net Cost Attributable to Pneumatic System:		54%
Percent of Total Net Cost Attributable to Hand Hauling:		46%

TABLE 38

COST ANALYSIS

MARTIN LUTHER KING HOSPITAL, LOS ANGELES

PNEUMATIC SOLID WASTE TRANSPORT SYSTEM

CAPITAL COSTS

Building Costs

Total Construction Costs	Total Square Feet	Cost/ Square Foot	Total Cubic Feet	Cost/ Cubic Foot
$23,540,000	551,251	$42.70	5,952,520	$3.95

1. Area Costs

	Square Feet	Value @ $42.70	Total
Laundry collector	728	$ 31,086	
Waste collector	255	10,889	
Filter, attenuator, and fan room	1,195	51,027	
Control panel	150	6,405	
Load stations (chute rooms), total	1,846	78,824	
Manholes	268	11,444	
Totals	4,442	$189,675	$189,675

2. Volume Costs

	Length, Ft.	Volume @ 20"D	Value @ $3.95	
Horizontal tubes, trash	1,400	3,053	$12,059	
Horizontal tubes, linen	900	1,962	7,750	
Air supply piping	520	1,134	4,479	
Vertical chutes	560	1,221	4,823	
	3,380	7,370	$29,111	$ 29,111

COST ANALYSIS
MARTIN LUTHER KING HOSPITAL, LOS ANGELES
PNEUMATIC SOLID WASTE TRANSPORT SYSTEM
(Continued)

3. Cost of Pneumatic System - Equipment and Installation	$425,000
TOTAL CAPITAL INVESTMENT FOR SPACE AND SYSTEM	$643,786
TOTAL CAPITAL COST PER YEAR, 7% INTEREST, 20-YEAR LIFE	$ 77,254

TABLE 39

COST ANALYSIS

MARTIN LUTHER KING HOSPITAL, LOS ANGELES

PNEUMATIC SOLID WASTE TRANSPORT SYSTEM

DIRECT COSTS

1. Labor	Avg. Rate w/Fringes	Avg. Hrs./ Month	Avg. Cost/ Month	Hrs./ Year	Cost/ Year	Total Dollars
Haul to chute loading room & load chutes	$3.42	534	$1,826	6,408	$21,915	
Load compactor		(no cost - automatic loading)				
Maintenance, corrective and preventive	4.80	71	341	852	4,090	
Total Labor Costs		605	$2,167	7,260	$26,005	$26,005

2. Bags to Transport Waste	No./ Month	Cost/ Month	No./ Year	Cost/ Year	
White plastic	16,004	$392	192,048	$4,700	
Total Supplies Cost		$392		$4,700	$ 4,700

3. Total Utilities (Power & Control)	Cost/Month	Cost/Year	
	$868	$10,416	$10,416
TOTAL DIRECT COSTS			$41,121

TABLE 40
COST ANALYSIS
MARTIN LUTHER KING HOSPITAL, LOS ANGELES
PNEUMATIC SOLID WASTE TRANSPORT SYSTEM

SUMMARY OF ANNUAL COSTS

CAPITAL COSTS AMORTIZED:		$ 77,254
DIRECT OPERATING COSTS:		
Labor	$26,005	
Transport Bags	4,700	
Utilities	10,416	
Total		$ 41,121
INDIRECT OPERATING COSTS:		
Downtime		$ 821
TOTAL COST PER YEAR:		$119,196
TOTAL COST PER MONTH:		$ 9,933
DEDUCTION OF FIXED CHARGES PER YEAR ASSIGNED TO LAUNDRY TRANSPORT (44%):		
Capital Costs	$33,992	
Utilities Costs	4,583	
Maintenance Costs	1,800	
Total Deductions		$ 40,375
NET COST PER YEAR FOR WASTE TRANSPORT:		$ 78,821
NET COST PER MONTH FOR WASTE TRANSPORT:		$ 6,568

COST ANALYSIS

MARTIN LUTHER KING HOSPITAL, LOS ANGELES

PNEUMATIC SOLID WASTE TRANSPORT SYSTEM

(Continued)

Total Pounds Transported per Month:		67,228
Total Cost per Pound of Solid Waste Transported:	$	0.10
Total Cubic Feet Transported per Month:		30,552
Total Cost per Cubic Foot of Solid Waste Transported:	$	0.22
Total Bags Transported per Month:		16,004
Total Cost per Bag of Solid Waste Transported:	$	0.41

TABLE 41

COST ANALYSIS

MARTIN LUTHER KING HOSPITAL, LOS ANGELES

HAND HAULED SOLID WASTE TRANSPORT SYSTEM

Labor

	Cost/Hr.	Hrs./Mo.	Cost/Mo.	Hrs./Yr.	Cost/Yr.	Totals
Pick up bags, load cart, walk to elevator	$3.42	332	$1,135	3,984	$13,625	
Elevator time, including waiting, loading, and unloading	3.42	73	250	876	2,996	
Walk from elevator & unload	3.42	11	38	132	451	
Total Labor Costs		416	$1,423	4,992	$17,073	$17,073

Bags to Receive and Transport Waste

	No./Month	Cost/Month	No./Year	Cost/Year	
Black plastic	7,000	$ 400	84,000	$ 4,800	
Large clear	15,000	518	180,000	6,216	
Waste liners	20,000	240	240,000	2,880	
Red isolation	1,600	84	19,200	1,008	
Total Supplies Costs		$1,242		$14,904	$14,904

Utilities

	Cost/Month	Cost/Year	
Elevator power, 25HP x 0.746 x $0.015 x 4.8 hrs./day x 7 x 4.33	$41	$492	$ 492

COST ANALYSIS

MARTIN LUTHER KING HOSPITAL, LOS ANGELES

HAND HAULED SOLID WASTE TRANSPORT SYSTEM

(Continued)

Depreciation of Equipment

	Cost/Month	Cost/Year	
Elevator, @ $60,000, 25-year life, used 20% of the time	$ 40	$ 480	
Carts, 8 @ $200, 10-year life	13	160	
Waste baskets, trash containers @ $3.50, 5-year life	207	2,485	
Total Depreciation Costs	$260	$3,125	$ 3,125

TABLE 42

COST ANALYSIS

MARTIN LUTHER KING HOSPITAL, LOS ANGELES

HAND HAULED SOLID WASTE TRANSPORT SYSTEM

SUMMARY OF ANNUAL COSTS

Labor	$17,073
Transport Bags	14,904
Utilities	492
Depreciation	3,125
TOTAL COST PER YEAR:	$35,594
TOTAL COST PER MONTH:	$ 2,966
Total Pounds Transported per Month:	44,253
Cost per Pound of Solid Waste Transported:	$ 0.07
Total Cubic Feet Transported per Month:	5,456
Cost per Cubic Foot of Solid Waste Transported:	$ 0.54
Total Cart Trips per Month:	485
Cost per Cart Load of Solid Waste:	$ 6.12
Cost per Bag Equivalent:	$ 0.38

TABLE 43

COST ANALYSIS

MARTIN LUTHER KING HOSPITAL, LOS ANGELES

END OF LINE SOLID WASTE HANDLING

Labor	Avg. Rate w/Fringes	Avg. Hrs./ Month	Avg. Cost/ Month	Hrs./ Year	Cost/ Year	Total Dollars
Load incinerator	$3.42	32	$109	384	$1,313	
Incinerator ash removal	3.42	40	137	480	1,642	
Clean compactor and bin	3.42	47	161	564	1,929	
Clean compactor and incinerator areas	3.42	21	72	252	862	
Maintenance, compactor and incinerator	4.80	13	62	156	749	
Total Labor Costs		153	$541	1,836	$6,492	$ 6,492
Off-Site Hauling						
Approximately 2 times per week @ $48			$411		$4,926	
Cleaning		(Included in labor above)				
Total Hauling Costs			$411		$4,926	$ 4,926
Amortization of Space						
Incinerator pad, 20-year life, 900 sq. ft. @ $15.50			$ 58		$ 698	
Loading dock, 20-year life, 600 sq. ft. @ $18.00			45		540	
Total Amortization Costs			$103		$1,238	$ 1,238
Depreciation of Equipment						
Incinerator, 10-year life			$574		$6,890	
Compactor, 10-year life			58		700	
Total Depreciation Costs			$632		$7,590	$ 7,590

COST ANALYSIS

MARTIN LUTHER KING HOSPITAL, LOS ANGELES

END OF LINE SOLID WASTE HANDLING

(Continued)

Utilities	Avg. Cost/ Month	Cost/ Year	Total Dollars
Incinerator	$16	$192	
Compactor	4	48	
Total Utilities Costs	$20	$240	$ 240

TABLE 44
COST ANALYSIS
MARTIN LUTHER KING HOSPITAL, LOS ANGELES
END OF LINE SOLID WASTE HANDLING

SUMMARY OF ANNUAL COSTS

Labor	$ 6,492
Off-Site Hauling	4,926
Space	1,238
Equipment	7,590
Utilities	240
TOTAL COST PER YEAR	$ 20,486
TOTAL COST PER MONTH	$ 1,707

Total Incoming Pounds Handled per Month	111,480
Cost per Incoming Pound Handled:	$ 0.02
Total Incoming Cubic Feet Handled per Month:	36,008
Cost per Incoming Cubic Foot Handled:	$ 0.05
Total Bags and Bag Equivalents Handled per Month:	23,763
Cost per Bag and Equivalent:	$ 0.07

TABLE 45

COST ANALYSIS

MARTIN LUTHER KING HOSPITAL, LOS ANGELES

SUMMARY OF TOTAL HOSPITAL SOLID WASTE COSTS

		Per Annum
1. Labor:		
Pneumatic System	$26,005	
Hand Hauled System	17,073	
End of Line System	6,492	
Total	$49,570	
Less Laundry % of P/N Maintenance (44%)	1,800	
Net Labor Cost		$ 47,770
2. Transport Bags:		
Pneumatic System	$ 4,700	
Hand Hauled System	14,904	
Total Transport Bag Cost		$ 19,604
3. Capital Costs:		
P/N System & Space	$77,254	
End of Line Space	1,238	
Total	$78,492	
Less Laundry % of P/N Capital (44%)	33,992	
Net Capital Cost		$ 44,500
4 Depreciation of Equipment:		
Hand Hauled System	$ 3,125	
End of Line System	7,590	
Total Depreciation		$ 10,715
5. Off-Site Hauling Contract:		$ 4,926

COST ANALYSIS
MARTIN LUTHER KING HOSPITAL, LOS ANGELES
SUMMARY OF TOTAL HOSPITAL SOLID WASTE COSTS
(Continued)

		Per Annum
6. **Utilities:**		
Pneumatic System	$10,416	
Hand Hauled System	492	
End of Line Systen	240	
Total	$11,148	
Less Laundry % of P/N Utilities (44%)	4,583	
Net Utilities Cost		$ 6,565
7. Indirect Costs - Downtime of P/N System:		$ 821
TOTAL NET COST PER YEAR:		$134,901
TOTAL NET COST PER MONTH:		$ 11,242
Total Pounds Disposed per Month		111,480
Net Cost per Pound Disposed:		$ 0.10
Total Cubic Feet Disposed per Month:		36,008
Net Cost per Cubic Foot Disposed:		$ 0.31
Total Bags and Bag Equivalents:		23,763
Net Cost per Bag and Equivalent:		$ 0.47

Percent of Total Net Cost Attributable to Pneumatic System: 68%

Percent of Total Net Cost Attributable to Hand Hauling: 32%

11- ECONOMIC FEASIBILITY OF PNEUMATIC SOLID WASTE TRANSPORT SYSTEMS

The term economic feasibility infers a comparison between available methods. To be feasible, a system must save labor or money over alternative ways of performing the same task; over a given time period the investment in the system, combined with the direct and indirect operating costs, must be self liquidating from the dollars that are saved. While other systems are possible (and are available) for solid waste transport, the basic comparison that should first be made is against hand hauling, involving carts, hallways, and elevators to move the waste, as this is the most common method used in hospitals. The basic determination must be made as to whether installation of the automated system saves hand labor and to what degree.

In reviewing the figures from the previous chapters, it can be seen that all three hospitals transport waste by both the pneumatic system and by hand carts, and in varying proportions, depending on their management system. In each hospital the hand hauled waste is transported at a lower cost per pound than the pneumatically transported material. The differences on a per cubic foot or volume basis are not as clear cut, varying from lower in cost to higher for the carted material.

Comparisons of costs by weight are more valid than by cube, as the bulk of the hand carted material consists of empty cartons with extremely large bulk. If they were slit or compressed on the floors to bring cube and weight to relatively the same ratio as the pneumatically transported wastes, comparisons on a cube basis would be more realistic.

TABLE 46 COST OF TRANSPORTING WASTE

	ST. MARY'S DULUTH		V.A. SAN DIEGO		MARTIN LUTHER KING LOS ANGELES	
ITEM	PNEUMATIC TUBE	HAND CARTED	PNEUMATIC TUBE	HAND CARTED	PNEUMATIC TUBE	HAND CARTED
Avg. pounds/day	882	1,391	1,115	3,330	2,218	1,460
$ cost per pound	0.13	0.06	0.15	0.03	0.10	0.07
Avg. cubic feet/day	382	185	557	1,018	1,008	180
$ cost per cu. ft.	0.30	0.41	0.30	0.09	0.22	0.54

Several factors contribute to the higher cost per pound for the waste transported by the pneumatic system.

The first, and most obvious, is the high net cost of the space occupied and the installed price of the pneumatic system equipment and its necessary utility lines. With total installed costs amortized from $36,548 to $77,254 per year, the annual use percentage devoted to solid waste transport amortizes from $7,310 to $32,591 to $43,262 for the three hospitals.

Secondly, while these are automated systems, they are not completely automatic. They require labor to load and, in one case, unload the system. They also require extensive labor for preventive and corrective maintenance. These labor factors require supervision and they involve other overhead, including fringe benefits.

Thirdly, each pneumatic system involves the cost of purchasing special bags to transport the waste, and the cost of utilities to supply power and run control circuits. Should they be "down" for maintenance work, they incur extra costs to transport waste by other methods.

Added together, all these costs directly attributable to the pneumatic systems range from $41,383 to $60,629 to $78,821 per year for the three hospitals.

Figuring an average wage for a "typical" waste handler in a hospital at $3.30 per hour, with fringes and overhead (or an average of $6,900 per year in 1973), the pneumatic system installed and operating annual costs for waste transport alone are the equivalent of the wages of from 6 to 8.7 to 11.4 full time positions for manual waste handling in the three hospitals. To these must be added the costs of the proportion of waste that is manually transported.

To determine the legitimate economic feasibility of the three systems, it is necessary to determine whether each can save what proportion of this labor per year.

The percent of total cost of solid waste transport attributable to the pneumatic system varied from 54 to 68 percent, yet the percent of the total weight handled by the systems ranged from only 25 percent to a high of 60 percent. Assuming a hospital elects to use an automated pneumatic transport system, then it must do so to the point where virtually no waste is transported outside the system. No hospital, no matter how large, can justify automation (at the installed costs of the past five years) unless it is used to the maximum extent possible.

All three survey hospitals had low utilization rates. All felt that this is caused by limitations in the system. Basically this comes down to the loading patterns and methods they had developed. The reasons for these do not appear completely valid.

Research by the survey team in other institutions with similar systems has revealed that all waste of all types can be sent through a pneumatic system with virtually no breakage problems, or plugging of the system, *if* the system is designed and installed correctly; *if* the unit loads are properly assembled and sized; *if* the transport bags are purchased to adequate specifications.

From a review of the make-up of the waste transported by hand, it is seen that the bulk of it is too large to enter the pneumatic system. This situation applies to a large percentage of the over 75 hospitals that have installed pneumatic tubes for waste transport. Very few have installed portable volume reduction and compacting equipment on the floors (ahead of the chute stations) to eliminate this problem. There appears no valid reason for this situation to continue.

Assuming each of the three surveyed hospitals *elected to send all its wastes through the pneumatic system*, and to spend the necessary additional labor or equipment dollars for floor volume reduction to achieve this, the cost figures for transport that were developed in the previous chapter would be considerably reduced.

The high capital cost for space and the installed equipment would now be spread over four times the total weight of waste at V.A. Hospital; almost three times at St. Mary's; and a 40 percent increase at Martin Luther King. This would obviously considerably reduce the cost per pound from the fixed charges. Utility costs and downtime costs, based on the way the systems are operated, would remain about the same as they are for the present partial utilization. Maintenance labor would also remain as a constant. Operating labor would rise at a different rate in each hospital, due to the differences in the systems and chute loading methods. Transport bags would rise virtually in proportion to the added waste being transported through the system. The following figures reveal these revised costs:

	ST. MARY'S DULUTH	V.A. SAN DIEGO	MARTIN LUTHER KING
Lbs. total waste transported/month	68,894	134,728	111,480
MONTHLY COSTS			
Capital cost, net	609	2,716	3,605
Labor, operating, and maintenance	2,828	1,831	2,381
Transport bags	2,660	782	470
Utilities	102	258	486
Downtime	21	176	68
TOTAL MONTHLY COSTS	6,220	5,763	7,010
COST PER POUND	0.09	0.04	0.06

It will be seen that these figures approach the per pound costs presently being incurred in each hospital for hand carting wastes.

In addition, each of the three hospitals is underloading the waste transport bags by almost 60 percent on a weight basis. Further, if the bags were actually mechanically sized and compacted before chute loading, bag costs and chute loading costs could be reduced by up to 75 percent in two of the hospitals including amortizing the cost of the floor compactors. These changes would mean monthly savings to the three hospitals and per pound transport costs as follows:

	NET SAVINGS PER MONTH	REVISED MONTHLY COST, NET	TRANSPORT COST PER LB.
St. Mary's Hospital	$1,993	$4,227	0.061
Veterans Administration Hospital	701	5,062	0.037
Martin Luther King Hospital	654	6,356	0.057

In the case of St. Mary's and the Veterans Administration, these figures are only slightly higher than their present per pound costs for hand carting wastes; in the case of Martin Luther King, the figure is lower.

If all the wastes had to be hand transported, would the costs compare to, be lower, or exceed the costs attainable from using the pneumatic system to the full extent? The revised pneumatic system costs are the equivalent of 7.3 full time positions in St. Mary's, 8.8 at the Veterans Administration, and 10.4 at Martin Luther King. Table 47 shows costs for hand hauling all waste.

Reviewing all the generation points of waste at each of the three hospitals; the weights and volumes generated; the hours of the day and frequency that transport must take place to equal the efficiency of removal of the pneumatic system; and the equipment that must be used; the cost figures shown on the following page would result from a complete hand transport system, using hallways and elevators, in each of the three surveyed hospitals.

Once the basis for comparison has been established in this matter, it is then possible to finally establish the differences in cost between transporting waste pneumatically and transporting waste completely by hand. These cost differences are then true monthly or annual savings as a result of installing the pneumatic system. Table 48 on page 240 shows these differences and hence savings, as a result of installing a pneumatic system in each of the three hospitals, *but with two major differences from the way the systems are currently being utilized.* The first figures show the operating costs and savings of the pneumatic system utilized to the full extent, transporting all waste in the building with none being hand hauled. The second group of figures shows the costs reduced even further and the savings consequently increased by loading each transport bag to the fullest extent in order to reduce the number of bags and hence the chute loading and waiting time labor, as well as the cost of transport bags.

Despite these impressive annual savings as a result of full utilization of the chute system, only in the case of the second alternate method can a recapture of investment be obtained. In the case of St. Mary's, the time period of 5-3/4 years shows that their system could be feasible from an economic standpoint. In the case of the V.A. Hospital and Martin Luther King, with payoffs as long as 49 and 58 years respectively, the time period to recapture the investment at 7 percent interest is so extensive that in all probability the system would be worn out halfway through the investment life.

It should be noted that if no interest were charged on the investment,

TABLE 47

ECONOMIC FEASIBILITY

MONTHLY COST TO HAND HAUL ALL HOSPITAL SOLID WASTE

	ST. MARY'S HOSPITAL		V.A. HOSPITAL		M. L. KING HOSPITAL	
Avg. no. of cart trips (to equal floor clearing @ hourly rate of present pneumatic system)	121		170		180	
1. LABOR:	Hrs/Mo	Cost/Mo	Hrs/Mo	Cost/Mo	Hrs/Mo	Cost/Mo
Empty waste containers, load carts, walk to elevator, elevator time (including waiting), walk to compactor, load compactor, return to elevator, elevator time (including waiting), walk to next pick-up point	1,359	$4,340	1,355	$4,525	1,871	$6,225
	Cost/Mo		Cost/Mo		Cost/Mo	
2. BAGS TO RECEIVE AND TRANSPORT WASTE:	$1,644		$2,162		$1,634	
3. UTILITIES:						
Elevator power, 25HP x 0.746 x $0.015 x hours used per month	114		188		143	
4. DEPRECIATION OF EQUIPMENT:						
Elevator @ $60,000, 25-year life, x period used	178		258		226	
Carts, 10-year life	9		24		39	
Trash containers, 5-year life	73		211		207	
Total costs per month	$6,358		$7,368		$8,474	
Number of pounds per month	68,894		134,728		111,480	
Cost per pound	0.09		0.05		0.08	

recapturing of investment could take place in under 20 years. However, in today's money market it is felt that this is an unreasonable approach from an accounting practice and that such capital investments should be amortized at least at 7 percent interest, when the prime rate has risen to 10 percent.

A review of amortization investment tables reveals an interesting fact. It clearly shows the upper limits of capital investment that can be made in the equipment and the occupied space for automated systems in any hospital, factored against varying amounts of savings per year.

If savings of $26,000 per year are to be realized from the installation of a system and a 7 percent interest rate is used for amortizing the equipment and occupied space, the maximum capital investment cannot exceed $270,000 if the investment is to be recaptured within 20 years through savings. If the realized savings fall to $18,000 per year, the upper limit on a capital investment, with 7 percent interest for the money, falls to $170,000 if the investment is to be amortized within this same 20 year period.

This clearly indicates that not only do pneumatic waste handling systems have to be utilized for both waste and laundry handling (regardless of the design of the system) but that they must be utilized to the fullest possible extent in order to save maximum labor; and most important that to be economically feasible the upper limits of investment in equipment and space are much lower than hospitals have been expending in installing such systems. Whether the desired operational results can be achieved under the inflationary conditions of 1974 through pneumatic transport systems costing much less than those that have been installed so far remains to be seen. Probably increased vendor competition, better designs, better hospital management practices, and improved system construction will achieve these results during the coming years. It would appear that unless these goals are achieved such systems will be one more example of adding to increased hospital costs without proven economic feasibility.

TABLE 48

ECONOMIC FEASIBILITY OF THE PNEUMATIC TRANSPORT SYSTEMS

		ST. MARY'S HOSPITAL	V.A. HOSPITAL	M. L. KING HOSPITAL
1.	Monthly costs with full utilization of the pneumatic system	$6,220	$5,763	$7,010
2.	Revised monthly costs by maximum reduction of bags transported	4,227	5,062	6,356
3.	Monthly costs of hand transporting total waste output	6,358	7,368	8,474
4.	Monthly savings - line 1 over line 3	138	1,605	1,464
5.	Annual savings - line 1 over line 3	1,656	19,200	17,568
6.	Monthly savings - line 2 over line 3	2,131	2,306	2,118
7.	Annual savings - line 2 over line 3	25,572	27,672	25,416
8.	Revised proportion of capital system investment for waste under full utilization	118,780	419,195	392,709
9.	Years to recapture waste use proportion of amortized capital investment in the pneumatic system; @ 7% interest.			
	through savings line 1 /line 3	infinity	infinity	infinity
	through savings line 2 /line 3	5-3/4	49	58

12. SYSTEM RATINGS AND COMPARATIVE ANALYSES

The principal automated systems to which a pneumatic tube transport system may be compared are:

1.) Selective, vertical-horizontal conveyor systems with tote boxes moving the waste.
2.) Automated cart systems, either run from an overhead rail, or from a strip or guide in the floor or adjacent baseboard.
3.) Wet pulping systems in which the waste is ground, mixed with water, and pumped through relatively small tubes to an extractor where approximately 50 percent of the water is removed. The damp pulp residue is then further handled.
4.) Grinding systems (the typical home kitchen-type disposal) in which the waste is ground and dumped directly into the sewer system from point of generation. (These may be installed throughout all sections of the building, or merely zoned in the lower levels and the waste moved to the zone receiver by manual horizontal methods combined, [or not combined] with gravity chutes.)
5.) Other pneumatic waste systems. In this study, all three systems are of a different type: (a) full vacuum, single bag loading; (b) full vacuum, multiple bag loading; and (c) gravity to vacuum, multiple bag loading.

In addition, comparisons must be made with the more conventional or "hand removal" systems, either hand movement by cart for both horizontal and vertical transfer, or the combinations of hand horizontal movement on the floors with gravity chutes handling the vertical movement, coupled with hand movement at the bottom of the gravity chutes to a central collection point.

Due to the very few hospitals that use automated methods other than pneumatic tube systems, it was determined that the comparative analyses in this study should be limited to:

a.) Comparisons and ratings between the three types of pneumatic tube systems themselves, and
b.) Comparisons between the pneumatic tube systems and the hand transport

systems that most (over 98 percent) of American hospitals employ.

In a study of this type, the final desired result is to assist architects, engineers, consultants, and users in selecting the "best" system for a particular project that may arise in the future. In short, to develop guidelines and "rate" such systems from several denominators.

In the Technical and Economic Analysis, we have identified many problems in solid waste management in general, and in pneumatic transport systems in particular. These range from architectural, design, mechanical, and operational deficiencies of the structure and physical equipment, to human operational, maintenance, and training problems, through problems in cost justification and economic feasibility. We have identified many environmental problems that affect the health and safety of the hospital personnel and possibly of the community.

In most previous comparative ratings of solid waste management systems, primary emphasis has been placed on economic considerations. These ratings usually compare systems based only upon how much the equipment costs to purchase, install, operate, and maintain. While economic considerations are important to hospital administrations, particularly in these days of rising costs, systems economics is only part of the picture.

Equally important are the improved environmental factors to be attained by both the hospital and the community. The spread of aerosols, atmospheric cross contamination, and other pollution, are reduced or increased in varying degrees by each different system. Fire and other safety hazards are reduced or increased depending on the equipment used and how it operates.

A major purpose for automating solid waste management is to reduce the spread of infection, accidents, and illnesses, thus providing advantages to patients, staff, and visitors. There are certain esthetic advantages which may be attained by reason of improved sanitation and a reduction in the number of sometimes noisy waste carts moving through the corridors. These considerations must also be taken into account in rating different systems and their success in achieving these goals, since the higher cost to achieve them may then be justifiable.

In comparing the available pneumatic systems, it is essential to break down the comparable elements of importance to the following:

- Economics
  - Total capital costs
  - Total direct costs
  - Total indirect costs
  - Cost per pound transported
  - Cost per cubic foot transported
  - Cost per bag transported
- Technical Design
  - Ease and safety of loading
  - Qualifications required of loading personnel
  - Speed of loading and clearing floors
  - Strength and size of chutes and tubes
  - Completeness and interfacing of components
- Environmental Acceptability
  - Sound levels
  - Odor levels
  - Bacterial contamination
  - Housekeeping practices
- User Acceptability
- Safety
  - Physical hazards
  - Fire hazards
  - Contamination hazards
- Reliability
  - Machinery
  - Personnel
- Maintainability
  - Corrective maintenance
  - Preventive maintenance and inspections
- Flexibility for Modification
- Potential for Expansion

Comparisons between systems must be based on both qualitative and quantitative factors. Some are arrived at by value judgements and qualified observations; some by value judgements of the results of interviews with hospital personnel; some by hard engineering data and physical measurements. Others are based on actual audits of labor expended, of equipment and other costs, and by physical testing.

The pneumatic transport systems of the three survey hospitals were compared against one another on an element by element basis. A combined numerical and narrative rating was assigned each element. Under this, a system was judged "best," "next best," or "least best" for that element. The "best" system element was assigned a rating of 3, the "next best" a rating of 2, and the "least best" a rating of 1. For example, in the element of economics, the system with the lowest cost per pound to transport solid waste by pneumatic tube was rated 3, the system with the highest cost was rated 1, and the remaining system was rated 2. In the event two or more systems were judged to be equal, they were assigned the same rating number and then the next lower number was omitted from the ratings. For example, if systems A and B were equally low in cost, they both would be given a rating of 3 and the remaining system a rating of 1. This same rationale was followed for the other elements of importance.

The matrix on the following pages presents the results of the solid waste transport systems comparisons.

PNEUMATIC SYSTEMS COMPARISON MATRIX

ELEMENT OF IMPORTANCE	V. A. HOSPITAL	MARTIN LUTHER KING HOSPITAL	ST. MARY'S HOSPITAL
ECONOMICS			
Total capital costs	$590,415 Rating 2	$643,786 Rating 1	$304,564 Rating 3
Total direct costs	$ 30,756 Rating 3	$ 41,121 Rating 2	$ 41,519 Rating 1
Total indirect costs	$ 2,112 Rating 1	$ 821 Rating 2	$ 255 Rating 3
Cost per pound transported	$ 0.15 Rating 1	$ 0.10 Rating 3	$ 0.13 Rating 2
Cost per cubic foot transported	$ 0.30 Rating 2	$ 0.22 Rating 3	$ 0.30 Rating 2
Cost per bag transported	$ 0.53 Rating 2	$ 0.41 Rating 3	$ 0.77 Rating 1
Total rating points	11	14	12
TECHNICAL DESIGN			
Ease and safety of loading	Key lock multiple bag loading by single individual. Up to 12 bags at a time. Vacuum at loading station may be a safety hazard. Rating 2.	Key lock multiple bag loading. No limit on number of bags. Vertical drop by gravity. No vacuum at loading station. Rating 3.	Single bag loading by many individuals. Vacuum at loading station. No key lock. Slow operation of system. Rating 1.

ELEMENT OF IMPORTANCE	V.A. HOSPITAL	MARTIN LUTHER KING HOSPITAL	ST. MARY'S HOSPITAL
TECHNICAL DESIGN (Cont.)			
Qualifications required of loading personnel	Training critical due to operation of diverter valves. Uses special personnel. Rating 1	System capable of complete random loading without operator training. Rating 3	Minimal training mostly concerned with type waste authorized and size of chute. Rating 2
Speed of loading and clearing floors	Requires 462 hours per month to clear floors and load chutes. Time to clear floors far exceeds loading time. 1.66 minutes per cubic foot to clear floors and load. Rating 2	Requires 534 hours per month to clear floors and load chutes. Time to clear floors far exceeds loading time. 1.05 minutes per cubic foot to clear floors and load. Rating 3	Requires 441 hours per month to clear floors and load chutes. Time to clear floors slightly less than loading time. 2.29 minutes per cubic foot to clear floors and load. Rating 1
Strength and size of chutes and tubes	Chute and tube diameter 16", 20-gauge metal. This is borderline as a minimum diameter and wall thickness. Rating 1	Tube diameter 20", 14-gauge in vertical gravity chutes. Horizontal vacuum tubes 20" diameter, 3/16" wall thickness. Rating 3	Chute and tube diameter 16", 20-gauge metal. This is borderline as a minimum diameter and wall thickness. Rating 1
Completeness and interfacing of components	System is enclosed and complete with air gap at compactor, which discharges directly into a large bin for hauling. Bin relatively accessible for truck pick-up. Value judgement rating 2	System is enclosed and complete through compactor, which discharges directly into a large bin for hauling. Bin easily accessible to truck. Value judgement rating 3	System is enclosed only to collector, then hand hauled outside to compactor, which is located at an undersized loading dock. Value judgement rating 1

ELEMENT OF IMPORTANCE	V.A. HOSPITAL	MARTIN LUTHER KING HOSPITAL	ST. MARY'S HOSPITAL
TECHNICAL DESIGN (Cont.)			
Efficiency of fan & filter installation	Excellent design of positive displacement single fan with well engineered vibration pad. 2 micron Rollomatic filter to protect fan and prevent escape of organisms in the exhaust air. Well engineered safety system to prevent fan damage due to high vacuum caused by tube plugging. Rating 3	Excellent design of positive displacement dual fans together with auxiliary fan to maintain negative pressure in chutes. Cycling of fans to ensure maximum performance. Well engineered vibration pads. 2 micron bag filter to protect fan and prevent escape of organisms in exhaust air. Well engineered safety system to prevent high vacuum Rating 3	Fan is open materials handling type. Vibration mounting and fan to motor coupling is border line. No pre or post fan filter to protect either fan blades or the environment. High vacuum safety system is slow acting. Motor mount damage already experienced due to fan blade imbalance. Rating 1
Efficiency of control circuitry	Control panel located in interstitullar space and difficult to reach quickly in emergency. No trouble shooting panel in Engineer's office. Rating 1	Excellent trouble shooting and control panel installed in fan room. However, no monitoring panel in Chief Engineer's office. Rating 3	Vendor circuitry was oversimplified. Hospital engineer developed and located in main engineering office an excellent control and monitoring panel. Rating 3
Total rating points	12	21	10

ELEMENT OF IMPORTANCE	V.A. HOSPITAL	MARTIN LUTHER KING HOSPITAL	ST. MARY'S HOSPITAL
ENVIRONMENTAL ACCEPTABILITY			
Sound levels	Predominantly low frequency sound. Average maximums ranged from 68-77 dB(A) with overall average of 65 dB(A) in corridors. Maximum average sound in system was inside fan room at 95 dB(A). Rating 1	Predominantly low frequency sound. Average maximums ranged from 59-63 dB(A) with overall average of 60 dB(A) in corridors. Maximum average sound in system was inside collector/compactor room at 98 dB(A). Rating 3	Predominantly low frequency sound. Average maximums ranged from 60-69 dB(A) with overall average of 62 dB(A) in corridors. Maximum average sound in system was inside fan room at 104 dB(A). Rating 2
Odor levels	Strongest odor at collector. One load station had Code 4 odor. 93% of all locations had Code 3 or less. Rating 2	Strongest odor at collector. One load station had Code 4 odor. 86% of all locations had Code 3 oe less. Code 4 odor close to private property. Rating 1	Strongest odor at compactor. No load station had Code 4 odor. 93% of all locations had Code 3 or less. Rating 3
Bacteriological contamination	No pathogenic bacteria were found inside the hospital. Rating 3	Pathogens were observed but were well below danger level. Rating 3	No hazardous bacteria were found. Rating 3
Housekeeping practices	Many cross-over problems. Ruptured bags, loose trash. Value judgement rating 2	Bag breakage on slide valve, which had not been properly cleaned. Evidence of unauthorized and unsanitary waste in system. Value judgement rating 2	No broken bags, litter, dust observed. Bag breakage solved by use of nylon bags. Value judgement rating 3
Total rating points	8	9	11

ELEMENT OF IMPORTANCE	V.A. HOSPITAL	MARTIN LUTHER KING HOSPITAL	ST. MARY'S HOSPITAL
USER ACCEPTABILITY	25.1% of total waste moved by tube. Trustability factor low. Diverter valve and personnel problems cause laundry to go to compactor, waste to laundry room. Many of staff feel they are serving the system rather than the system serving them. Value judgement rating 1	60.3% of total waste moved by tube. Trustability factor high. Loading is relatively easy and fast, causes few problems. Staff generally was pleased with system. Value judgement rating 3	38.8% of total waste moved by tube. Trustability factor medium. System slow, requires much waiting to load. Many of staff feel they could clear floors faster by hand. Some staff also feel tube too small. Value judgement rating 2
Total rating points	1	3	2
SAFETY			
Physical hazards	Hazardous condition in key lock loading due to vacuum pull on chute door. No unsafe or hazardous conditions for maintenance staff except high noise level in fan room. Value judgement rating 1	Possible hazardous condition exists for maintenance staff in slide valve rooms. High noise level in fan room. No unsafe consitions for operating staff. Value judgement rating 2	No unsafe or hazardous conditions for operating or maintenance staff except high noise level in fan room. Value judgement rating 3
Fire hazards	Meets NFPA Code for tube size. Has fusible link fire dampers but these occasionally cause bag ripping. No indication of fire in system. Value judgement rating 2	Exceeds NFPA Code for tube size. Has fusible link fire dampers but these occasionally cause bag ripping. No indication of fire in system. No hopper in load chute might contribute to chute fires as could trash on slide valve. Value judgement rating 3	Meets NFPA Code for tube size. Has fusible link fire dampers but these occasionally cause bag ripping. No indication of fire in system. Fan room is marginal due to lint conditions. Value judgement rating 1

ELEMENT OF IMPORTANCE	V.A. HOSPITAL	MARTIN LUTHER KING HOSPITAL	ST. MARY'S HOSPITAL
SAFETY (Cont.)			
Contamination hazards to patients and staff	Only non-pathogenic fomites were found inside hospital. Value judgement rating 3	Small colony of krebsiella found on laundry floor. Not considered hazardous to patients or staff. Value judgement rating 3	Only non-pathogenic fomites were found inside hospital. Value judgement rating 3
Total rating points	6	8	7
RELIABILITY			
Machinery	Shutdowns for as long as 30 days occurred. Many problems with diverter valves which required installation of new valves. Original square collector required replacement to reduce bag breakage. Travel timers required replacement several times. No serious problems with electrical or hydraulic systems. Quick acting relief valve ahead of fan operates efficiently. Highest amount of downtime of all three systems. Value judgement rating 1	Waste bin under collector, not supplied by system vendor, has sloping sides which tend to bridge and slow the drop to the compactor. Air valves and loading chute door locks have required occasional replacement. Filter ahead of fan most sophisticated of all three, giving 100% protection. No serious problems with electrical or hydraulic systems. Lowest amount of downtime. Value judgement rating 3	Originally had excessive vacuum and vibration due to bag plugs. Caused damage to tubes, fittings, and mounting hangers. Experienced tube collapses and seam ruptures. 20-gauge metal in bends and tube is on light side. Lack of filter ahead of fan has caused an unbalanced condition and vibration sufficient to crack fan motor base. Originally had freezing weather problems with roof dampers. Corrected by air drying units. No serious problems with electrical or hydraulic systems. Relief valve ahead of fan least sophisticated Relatively low amount of downtime. Value judgement rating 2

ELEMENTS OF IMPORTANCE	V.A. HOSPITAL	MARTIN LUTHER KING HOSPITAL	ST. MARY'S HOSPITAL
RELIABILITY (Cont.)			
Personnel	Has experienced plugging from improper loading. This should be easy to control since only designated people load chutes. Has experienced cross-over problems but this is due mostly to faulty diverters rather than personnel. Value judgement rating 1	Has experienced plugging from improper loading. This should be easy to control since only designated people load chutes. Has experienced cross-over problems due 100% to operator carelessness. Value judgement rating 3	Has experienced plugging from improper loading. This is difficult to control since many people load chutes. Has experienced cross-over problems due 100% to operator carelessness. Value judgement rating 2
Total rating points	2	6	4
MAINTAINABILITY			
Corrective maintenance	Highest amount of corrective maintenance required on this single tube system (454 hours yearly average). Most of this was devoted to replacement of system components such as collectors and diverters to decrease number of bags breaking and system plug ups. Value judgement rating 1	Least amount of corrective maintenance required on this heavy wall two-tube system (171 hours yearly average). Bulk of this was devoted to correcting situations in linen collector room and valve rooms where vacuum pulled plaster from walls due to inadequate venting. Value judgement rating 3	Very close to highest amount of corrective maintenance required on this light wall two-tube system (424 hours yearly average). Most of this devoted to correcting damage to tubes, fittings, and hangers caused by high vacuum and excessive vibration. Most problems due to plug ups resulting in replacement of collapsed tubes and riveting ruptured seams. Value judgement rating 2

ELEMENT OF IMPORTANCE	V.A. HOSPITAL	MARTIN LUTHER KING HOSPITAL	ST. MARY'S HOSPITAL
MAINTAINABILITY (Cont.)			
Preventive maintenance and inspections	Devotes yearly average of 813 total hours for preventive maintenance and inspections combined. Part of a man's full time is assigned on call to continuously check system operation. Most preventive maintenance devoted to lubrication, clean and changing filters, cleaning compactor. Value judgement rating 1	Devotes yearly average of 240 hours to preventive maintenance and 441 hours to inspections, or 681 total hours to this catagory. Most preventive maintenance spent on lubrication, cleaning filters, cleaning compactor. Value judgement rating 3	Devotes yearly average of 284 hours for preventive maintenance and none to inspection of the system. Most preventive maintenance spent on lubrication, cleaning dust from fan blades, and cleaning lint screens. Value judgement rating 2
Total rating points	2	6	4
FLEXIBILITY FOR MODIFICATION	The prime modification here could be the addition of automated "end of the line" equipment. Hospital is presently modifying its system to add a general purpose incinerator. Value judgement rating 2	This system could be modified for automated "end of the line" equipment. Are currently considering reduction equipment to replace compactor. Value judgement rating 3	This system should have a direct loading arrangement from the collector to the compactor to avoid possible contamination problems and to save labor. Because of hospital limited dock facilities, will require additional structural changes. Value judgement rating 1
Total rating points	2	3	1

ELEMENT OF IMPORTANCE	V.A. HOSPITAL	MARTIN LUTHER KING HOSPITAL	ST. MARY'S HOSPITAL
POTENTIAL FOR EXPANSION	Not only must all expansion piping be under a vacuum to expand this system, with much higher fan and filter capacity, but the electrics and control system of a single tube system are the most complex of all systems.	A gravity to vacuum system is basically simpler to expand than others. If a wing is added to the hospital, a relatively simple vertical chute could be added in the new wing with a single horizontal tube under vacuum running to it. Additional fan capacity would be minimal.	To expand a full vacuum system requires both additional vertical chutes and horizontal tubes, all of which must be under a vacuum, thus requiring much larger fans and filters. Further, the electrics of this type system are more complex than gravity to vacuum.
	Value judgement rating 1	Value judgement rating 3	Value judgement rating 2
Total rating points	1	3	2
TOTAL RATING POINTS FOR ALL ELEMENTS	34	59	41

As stated at the beginning of this chapter, comparisons were made between the pneumatic tube systems and the more conventional hand transport systems used by most hospitals in the United States today. The comparisons are presented as a composite of the three pneumatic systems as compared to a composite of three hand transport systems with the capability of hauling all solid waste from the three hospitals. Where the rating elements could be quantified, they are presented as individual values for each system, and the average value among all the systems. In the case of narrative rating elements, the descriptions cover the essential features of all systems in the three hospitals and the ratings are assigned on the basis of value judgements.

In making this type comparison, different elements of importance must be used than were used in comparisons between the three pneumatic systems, since some elements are unique to pneumatic systems and are not applicable to hand transport systems. The comparable elements of importance for this portion of the analysis were broken down to the following:

- Economics
  - Total costs per month
  - Total costs per pound transported
  - Total costs per cubic foot transported
  - Total costs per bag transported
- Qualifications Required of Transport Personnel
- Speed of Clearing Floors
- Interfacing of Components
- Reliability
- Maintainability
- User Acceptability
- Environmental Acceptability
- Safety
  - Sound levels
  - Odor levels
  - Contamination
  - Housekeeping practices

Certain assumptions, based on observations, were made in rating the cost elements. First, a hand hauled cart will hold, on the average, 16 bags of waste. The bags to receive and transport waste were actually costed out. The cost of utilities, and depreciation of elevators, carts, and trash containers were factored. Labor includes time to empty waste containers, load carts, walk to elevator, elevator time (including waiting), walk to compactor, load compactor, return to elevator, elevator time (including waiting), and walk to next pick-up point. The cost figures for the pneumatic systems are based on net cost assigned to hauling waste only. A rating system of 2 for "best" and 1 for "least" is used here in a comparable manner to the 3-point system used in the comparisons between pneumatic systems.

The matrix on the following pages presents the results of the comparisons between the composite of the three pneumatic systems and the composite of the three manual systems.

PNEUMATIC VS. HAND SYSTEMS COMPARISON MATRIX

ELEMENT OF IMPORTANCE	PNEUMATIC SYSTEM	HAND SYSTEM
ECONOMICS		
Total individual costs per month	$3,449 to $5,052 to $6,568	$6,358 to $7,368 to $8,474
Average value	$5,023	$7,400
Rating	2	1
Total individual costs per pound	$ 0.10 to $ 0.13 to $ 0.15	$ 0.05 to $ 0.08 to $ 0.09
Average value	$ 0.13	$ 0.07
Rating	1	2
Total individual costs per cubic foot	$ 0.22 to $ 0.30 to $ 0.30	$ 0.16 to $ 0.24 to $ 0.37
Average value	$ 0.27	$ 0.26
Rating	2	2
Total individual costs per bag	$ 0.41 to $ 0.53 to $ 0.77	$ 0.30 to $ 0.36 to $ 0.54
Average value	$ 0.57	$ 0.40
Rating	1	2
Total rating points	6	7
QUALIFICATIONS REQUIRED OF TRANSPORT PERSONNEL	Requires minimal training to learn routine of making rounds and unlocking chute door, or randomly loading an unlocked chute.	Requires considerable training and experience to learn routine and accomplish rounds efficiently and without interference.
Rating	2	1
SPEED OF LOADING AND CLEARING FLOORS	Waste bags can be cleared from patient and ancillary areas much faster than by cart. Requires 441 hours to 462 hours to 534 hours per month to clear floors and load chutes.	Carts are bulky yet handle per hour much less waste in vertical transport than chutes. Requires 1,355 hours to 1,359 hours to 1,871 hours per month to clear floors, haul to compactor, and return.
Average value	479 hours	1,528 hours
Rating	2	1

ELEMENT OF IMPORTANCE	PNEUMATIC SYSTEM	HAND SYSTEM
INTERFACING OF COMPONENTS	Systems are enclosed and complete with an air gap at compactor, except one which is complete to compactor, then hand hauled to compactor.	System is completely open to the compactor, except that waste is encapsulated in plastic bags.
Rating	2	1
RELIABILITY	All systems experience plugging and shut downs, one system down for as long as 30 days. Lack of fan air filter in one system has caused dust build-up and vibrations in fan sufficient to crack motor mount. 20-gauge metal in some tubes is borderline, contributing to tube collapse.	Reliability affected only by availability of personnel to push carts and operation of one elevator.
Rating	1	2
MAINTAINABILITY		
Individual values	Averages 171 hours to 424 hours to 454 hours per year for corrective maintenance. Averages 284 hours to 681 hours to 813 hours per year for preventive maintenance and routine inspections. One system has no routine inspections.	Requires cleaning of carts plus routine inspections and maintenance of elevator at 150 hours per year.
Average values	Corrective, 350 hours Preventive and inspections, 593	150 hours
Rating	1	2

ELEMENT OF IMPORTANCE	PNEUMATIC SYSTEM	HAND SYSTEM
USER ACCEPTABILITY	Trustability factor is low for two systems, relatively high for the third. Low factor due to slowness of system in one case, requiring much waiting time to load, and in the other due to many cases of waste and laundry bags crossing over. High factor due to easy and fast loading.	Trustability factor medium to high since the system will work. Esthetic value rating medium. Creates traffic problems and noise in the corridors.
Value judgement rating	1	1
ENVIRONMENTAL ACCEPTABILITY		
Sound levels	Average maximums ranged from 63 dB(A) to 69 dB(A) to 77 dB(A) in corridors outside chute loading rooms. Overall average value per hospital ranged from 60 dB(A) to 62 dB(A) to 65 dB(A) in the corridors outside chute loading rooms.	Averages 5-10 dB(A) above sound of chute loading stations, measured in corridors.
Average values	Maximum level 70dB(A) Average level 62 dB(A)	Maximum level 77dB(A) Average level 69 dB(A)
Rating	2	1
Odor levels	Odor, if any, as measured in corridors, coming from chute loading rooms, is low but when present is persistent.	Odor, if any, coming from a waste cart is transient. (This assumes all waste is transported in tied or sealed bags.)
Value judgement rating	1	2
Contamination	No dangerous contamination noted inside hospitals attributable to pneumatic systems. The risk is lower inside patient areas.	The risk is higher due to exposed conditions in carts and longer contact of bags with carts.
Value judgement rating	2	1

ELEMENT OF IMPORTANCE	PNEUMATIC SYSTEM	HAND SYSTEM
ENVIRONMENTAL ACCEPTABILITY		
Housekeeping practices	Bag breakage and waste spread within pneumatic system is confined. Negative pressure leads odors and contamination to fan and filter.	Bag breakage in cart loading and within carts can spread aerosols through hospital corridors. Theoretically carts should be cleaned after each trip if breakage or leakage occurs.
Value judgement rating	2	1
Total rating points	7	5
SAFETY	No hazardous or unsafe conditions were found, except high noise levels in all fan rooms and, in one hospital, a physically hazardous condition to maintenance personnel in slide valve room.	Potential safety hazard to pedestrians and wheel chair patients in corridors and elevators.
Value judgement rating	2	1
TOTAL RATING POINTS FOR ALL ELEMENTS	24	21

COMPARISON RATING SUMMARY

	PNEUMATIC VS. PNEUMATIC			PNEUMATIC VS. HAND	
	V.A. HOSPITAL	M.L.KING HOSPITAL	ST. MARY'S HOSPITAL	PNEUMATIC SYSTEM	HAND SYSTEM
Overall total rating points	34	59	41	24	21

SUMMARY OF SYSTEMS RATINGS AND COMPARISONS

As stated earlier in this chapter, the previous comparisons and ratings were based on both quantitative and qualitative factors. Some were based on audit of cost and labor figures, measurements and physical testing, and some by value judgments based on qualified observations, past experience, and interviews on site. Based on this, it is our conclusion that, after comparing and evaluating the three pneumatic systems with one another, the heavy-wall, two-tube, gravity to vacuum system at Martin Luther King is the "best" system, even though it is the most expensive. The thin-wall, two-tube, full vacuum systems at St. Mary's Hospital was judged to be "second best," when compared and evaluated with the other penumatic systems. The thin-wall, single-tube, full vacuum system at Veterans Administration Hospital was judged "third best" when compared and evaluated with the other pneumatic systems.

The composite of the three pneumatic systems, compared to the composite of three hand systems, was judged slightly "better" overall, even though they rated lower in the economic factors. This is due primarily to the higher ratings of the pneumatic systems in environmental factors and speed and clearing of floors.

The pneumatic solid waste handling system at Martin Luther King Hospital was significantly more expensive to install than the other two pneumatic systems. It thus appears that this is a case of higher installation cost being justifiable in order to achieve other advantages and help meet the goals of improving the internal environment of the institution.

APPENDIX

A GLOSSARY OF TERMS APPLICABLE TO SOLID WASTE MANAGEMENT
IN
HEALTH CARE FACILITIES

ANIMAL WASTE - Waste generated from animal care or use; including secretions, tissue, remains, droppings, bedding for cages (such as sawdust, etc.).

BAGGING - The deposition of solid waste in a paper or plastic bag for storage or transport.

BIODEGRADABLE - Waste material which is capable of being broken down by bacteria into basic elements. Most organic waste, such as food remains and paper, is biodegradable.

BIOLOGICAL WASTES - Waste contaminated with or made up of animal or plant tissue, secretions, remains, droppings, or other elements.

CHARGE - The quantity of solid waste introduced into a furnace at one time.

CHEMICAL WASTES - Any chemical or mixture of chemicals which require special consideration for disposal.

CLASSIFICATION - To arrange or sort waste materials into uniform categories or classes. Usually implies accurate grading by organic, inorganic, size, weight, color, or shape, etc.

COLLECTION - The act of removing solid waste from a storage point.

COLLECTION CENTER - A place or facility designed to accept waste materials from individuals or mechanical devices (such as conveyors, carts, or transport tubes). The term can also be used to mean a central receiving point for waste material collected by a government or private agency.

COMBUSTIBLES - Various materials in the waste stream which are burnable. In general, these are organic in nature: paper, plastics, wood, and food wastes.

COMPACTOR - Any power driven mechanical equipment designed to compress and thereby reduce the volume of waste materials.

CONTAINERIZE - The deposition of solid waste into metal, plastic, or other containers for storage or transport.

CONTAMINATED WASTES - Waste which has been soiled, stained, corrupted, or infected by contact, association, or use.

DISINFECTION - Killing of infectious agents outside the body by chemical or physical means directly applied.

DISPOSABLE - A product intended for single or limited use before being discarded.

DISPOSAL - The orderly process of discarding useless or unwanted material.

DUMP - An open land site where waste materials are burned, left to decompose, rust, or simply remain. In most localities, dumps are being phased out because of the problems which they cause, such as water pollution, creation of unsanitary conditions, and general unsightliness. Some dumps are left burning as waste is accumulated. This practice does not lend itself to control, and, therefore, very little of the waste is actually consumed by fire. The burning also generates obnoxious smoke, fumes, and ash particles.

ECOLOGY - The science that deals with the interrelationships of organisms and their living and non-living surroundings.

ECOSYSTEM - The interdependence of organisms and their surroundings.

EMISSIONS (GASEOUS) - Waste gases released into the atmosphere as the product of combustion.

ENVIRONMENT - The air, the water, and the earth, sometimes called the biosphere. Alternatively, homes, institutions, and other places of residence or work.

ENVIRONMENTAL SYSTEM - The interaction of an organism or group of organisms with its natural and manmade surroundings.

FOMITE - Inanimate objects such as clothing, dishes, toys, books, that may be contaminated with infectious agents and serve in their transmission.

FOOD WASTE - Animal and vegetable waste resulting from the handling, storage, sale, preparation, cooking, and serving of food; commonly called garbage.

GARBAGE - Waste materials which are likely to decompose or putrefy. Usually contain food wastes from a kitchen, restuarant, grocery store, slaughter house, or food processing plant.

GRINDING - The mechanical pulverization of solid waste.

HAUL DISTANCE - (1) The distance a collection vehicle travels from its last pickup stop to the solid waste transfer station, processing facility, or sanitary landfill. (2) The distance a vehicle travels from a solid waste transfer station or processing facility to a point of final disposal. (3) The distance that cover material must be transported from an excavation or stockpile to the working face of a sanitary landfill.

HAUL TIME - The elapsed or cumulative time spent transporting solid waste between two specific locations.

HAZARDOUS WASTE - The waste from a hazardous material: which is any element, compound, or combination thereof, that is flammable, corrosive, detonable, toxic, radioactive, an oxidizer, an etiological agent, or is highly reactive, and that because of handling, storing, processing, packaging, or transporting may have detrimental effects upon operating and emergency personnel, equipment, the workplace, or the environment. Waste which requires special handling to avoid illness or injury to persons, or damage to property.

INCINERATION - The controlled process by which solid, liquid, or gaseous combustible wastes are burned and changed into gases and the residue produced contains little or no combustible material.

INCINERATOR - An engineered apparatus used to burn waste substances and in which all the factors of combustion--temperature, retention time, turbulence, and combustion air--can be controlled.

INCINERATOR RATED CAPACITY - The number of tons of solid waste that can be processed at an incinerator per 24-hour period when specified criteria prevail. Alternatively, the pounds per hour that can be burned.

INFECTED PERSON - Infected persons include both individuals with manifest disease and those with inapparent infection.

INFECTION - The entry and development or multiplication of an infectious agent in the body of man or animal. Infection is not synonymous with infectious disease; the result may be inapparent or manifest. The presence of living infectious agents on exterior surfaces of the body or upon articles of apparel or soiled articles is not infection, but contamination of such surfaces and articles.

INFECTIOUS AGENT - An organism, mainly microorganisms (bacterium, protozoan, spirochete, fungus, virus, rickettsia, bedsonia, or other) but including helminths, capable of producing infection or infectious disease.

INFECTIOUS DISEASE - A disease of man or animal resulting from an infection.

INFECTIOUS WASTE - Waste originating from the diagnosis, care, or treatment of a person or animal which has been, or may have been, exposed to a contagious or infectious disease.

INSTITUTIONAL WASTE - Waste originating from educational, health care, research, and similar institutions.

ISOLATION WASTE - Waste originating from the diagnosis, care, or treatment of a patient placed in isolation because of a known or suspected infectious disease.

JUNK - Unprocessed materials suitable for reuse or recycling.

LABORATORY WASTE - Waste generated through the activities of the laboratory which may be innocuous, hazardous, or infectious, solids, or liquids.

MANUAL SEPARATION - The separation of waste materials by hand. Sometimes called hand picking, manual separation is done in the home or office by keeping garbage separate from newspapers, or in a recovery plant by picking out large cardboard or metal objects.

MANURE - Primarily the excreta of animals; may contain some spilled feed or bedding.

MEDICALLY CONTAMINATED WASTE - Waste originating from activities associated with patient diagnosis, care, or treatment. Also medical waste.

MILLED REFUSE - Solid waste that has been mechanically reduced in size by the grinding, or pulverizing, or hammering action of an attrition mill, "hogg," or dry grinder.

MOISTURE CONTENT (SOLID WASTE) - The weight loss (expressed in percent) when a sample of solid waste is dried to a constant weight at a temperature of 100 C to 105 C.

OPEN BURNING - Uncontrolled burning of wastes in the open or in an open dump.

PATHOGEN - An organism capable of producing disease.

PATHOCENIC WASTE - Waste contaminated with an organism capable of producing disease.

PATHOLOGICAL WASTE - Tissues, parts, and organs of humans and animals.

PNEUMATIC COLLECTION (SOLID WASTE) - A mechanical system for conveying solid waste through transport pipes. When the system is in operation, a vacuum is developed and a high velocity air stream is drawn through pipes. Waste, which is dropped into this moving air stream, is carried to a collection point.

POLLUTION - The condition caused by the presence in the environment of substances of such character and in such quantities that the quality of the environment is impaired or rendered offensive to life.

POLYVINYL CHLORIDE (PVC) - A common plastic material that releases hydrochloric acid when burned.

PYROLYSIS - The chemical decomposition of a material by heat in the absence of oxygen.

RADIOACTIVE WASTE - Waste contaminated with a substance which emits ionizing radiation.

RECLAMATION - The restoration to a better or more useful state, such as land reclamation by sanitary landfilling, or the obtaining of useful materials from solid waste.

RECOVERY - The process of obtaining materials or energy resources from solid waste. Synonyms: Extraction, Reclamation, Salvage.

RECYCLING - The process by which waste materials are transformed into new products in such a manner that the original products may lose their identity.

REFUSE - A generally used term for solid waste materials.

RESIDUE - Material that remains after gases, liquids, or solids have been removed.

REUSE - The use of a waste material or product more than once. For example, a soft drink bottle is reused when it is returned to the bottling company and refilled.

RUBBISH - A general term for solid waste--excluding food waste and ashes--taken from residences, commercial establishments, and institutions.

SALVAGE - The utilization of waste materials.

SANITARY LANDFILL - A site where solid waste is disposed using sanitary landfilling techniques.

SANITATION - The control of all the factors in man's physical environment that exercise or can exercise a deleterious effect on his physical development, health, and survival.

SCRAP - Waste material which is usually segregated and suitable for recovery or reclamation.

SEPARATION - The systematic division of solid waste into designated categories; e.g. removing glass containers, metal cans, etc. from general waste.

SHREDDER - A mechanical device used to break up waste materials into smaller pieces. The pieces are usually in the form of irregularly shaped strips.

SOLID WASTE - Useless, unwanted, or discarded material with insufficient liquid content to be free flowing.

SOLID WASTE DENSITY - The number obtained by dividing the weight of solid waste by its volume.

SOLID WASTE MANAGEMENT - The purposeful, systematic control of the generation, storage, collection, transport, separation, processing, recycling, recovery, and disposal of solid wastes.

SOURCE OF INFECTION - The thing, person, object, or substance from which an infectious agent passes immediately to a host.

SPECIAL WASTE - Waste that requires extraordinary management.

STERILIZATION - The destruction, by chemical or physical means, of a microorganism's ability to reproduce; to render something barren.

STORAGE - The interim containment of solid waste, in an approved manner, after generation and prior to ultimate disposal.

SURGICAL AND AUTOPSY WASTE - Waste that includes tissue, limbs, organs, placentas, and similar types of materials.

TOXIC WASTE - Waste contaminated with any substance which has the capacity to produce personal injury or illness to man through ingestion, inhalation, or absorption.

TRANSFER STATION - A site at which solid waste is concentrated and then taken to a collection center of a processing facility.

TRANSPORT - The movement of solid waste subsequent to collection.

TRASH - (Same as Rubbish) - A general term for solid waste--excluding food waste and ashes--taken from residences, commercial establishments, and institutions.

VOLUME REDUCTION - To process waste materials so as to decrease the amount of space the materials occupy. Complete conventional incineration can reduce volume by 90 percent while high temperature incineration achieves as much as 98 percent. Compaction systems can also reduce volume by 50 to 80 percent.

WASTE - The useless, unwanted, or discarded materials resulting from normal community activities, including solids, liquids, and gases.

WASTE GENERATION - The act or process of producing solid waste,

WASTE PROCESSING - An operation such as shredding, compaction, composting, and incineration, in which the physical or chemical properties of wastes are changed.

WET PULPING - The mechanical size reduction of solid wastes that have been wetted to soften the water absorbing constituents (such as paper and cardboard).